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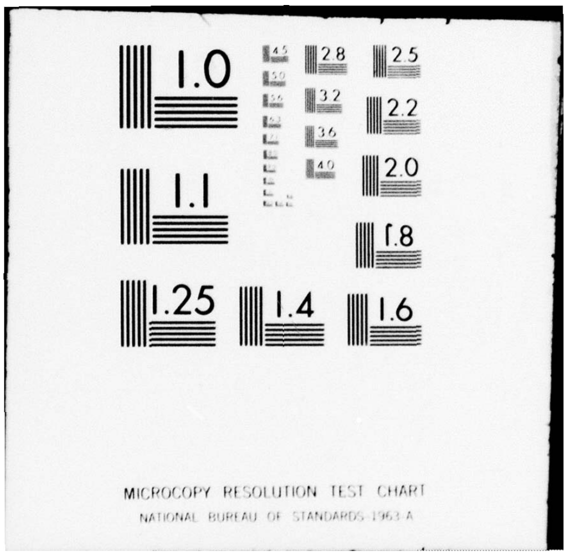
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RETENTION AND TRANSFER OF TRAINING ON A PROCEDURAL TASK; INTERACTION OF TRAINING STRATEGY AND COGNITIVE STYLE

FINAL REPORT

Steven L. Johnson

Calspan Report No. DJ-6032-M-1

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ABSTRACT

This study investigated the effectiveness of three different training strategies with respect to initial training, retention, and transfer of training. In addition to investigating the relative merits of the three strategies, the possibility of matching the instructional strategy and the trainee's cognitive style was evaluated. There is growing research support for the contention that different individuals utilize different means of encoding and/or storing information. The effect of these differences with respect to initial training, retention, and transfer of training was addressed in the context of a realistic task. The particular task used was representative of the many sequential procedures performed which range from operating master control panels in industrial plants to normal and emergency procedures in air vehicles.

The instructional strategies evaluated during the study were designed to require varying degrees of imagery utilization through reductions in the stimuli that provide visual cueing and feedback. The standard for comparing the effectiveness of these strategies was the conventional "repetition" of the task on the operational equipment or high fidelity mockups (simulations) of the equipment. The individual trainee's vividness of mental imagery was the aspect of cognitive style that was investigated with respect to performance within the three training strategies.

The results of the study indicate that: (1) vividness of imagery does interact with training strategy, (2) training devices <u>do not</u> need high fidelity to be effective in training procedural tasks, and

(3) the use of training strategy that requires the trainee to provide his own cueing and feedback from memory <u>is effective</u> in increasing the retention of procedure-following skills, independent of cognitive style. These results have important implications for both the dollar cost and logistics of initial and refresher training, as well as for the retention efficiency of an important aspect of the human's present job description.

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INTRODUCTION

The role of the human operator in today's systems has been rapidly changing in character. The human operator is seldom an on-line manual controller in today's automated (computerized) environment. For example, the days of the goggles and white scarf in an open aircraft cockpit are gone forever. The rate at which information must be processed and control accomplished in modern systems is often beyond the human's capabilities. Therefore, the role of the human is becoming increasingly that of a process initiator, monitor, and rectifier.

The implication of this changing role is that the individual tasks that the human operator performs are now more procedural in nature, rather than involving fine tuned motor control. Webster (1974) defines a procedure as "the act, method, or manner of proceeding in some process or course of action; esp., the sequence of steps to be followed" (P1133). The concept of procedurally following a sequence of steps is becoming more predominant in areas ranging from troubleshooting a defective piece of equipment during repair to the use of operations research techniques in evaluating the product marketing possibilities in a business environment. In the areas involving a human operator (e.g., piloting an aircraft, setting up and monitoring a nuclear reaction process), not only are procedural tasks becoming more frequent, but the criticality of the tasks is often high. In many emergency situations, the corrective action is a step-by-step procedure, with decision points, which the operator must perform quickly and correctly. A complicating factor pertaining to emergency procedures is that generally they are performed infrequently. Therefore, the operator encounters extensive intervals of not performing the procedure. The research literature (discussed in another section) illustrates that procedures are particularly susceptible to forgetting during relatively short intervals of no practice.

Although the trend in the human's job requirements is toward being able to follow step-by-step procedures correctly, the research literature on human capabilities and limitations in this area is relatively sparse. That is, relative to the extent of the research based on continuous perceptual-motor control, procedure-following types of tasks have received much less recent attention. Although the advanced technology behind today's hardware and software has altered the human's job requirements, the research effort within the behavioral technology realm has not been sufficiently responsive.

The present study attempted to integrate some of the research areas that have recently been receiving attention (i.e., cognitive styles; training device effectiveness; and learning, retention, and transfer) and relate them to the area of training operators to perform a realistic procedure following task. The next three sections will discuss the research related to: (1) the relationship between cognitive styles and the effectiveness of different training strategies, (2) training device characteristics and training effectiveness, and (3) the capabilities of humans to learn and retain a skill and to transfer that skill from one task to another.

Mental Imagery As A Cognitive Style

The term "cognitive style" is presently being used in many different contexts. For example, it is used by cognitive psychologists to describe different modes of information processing and by clinical psychologists to categorize people as to personality variables. Kagen, Moss, and Sigel (1963) provide a definition of cognitive style as "stable individual preferences in the mode of perceptual organization and conceptual categorization of the external environment" (p. 74). Modrick, Levit, Alden, and Henke (1975) discuss the idea that individuals apparently have "subconscious" preferences for organizing information and that these preferences are stable over time. The two essential elements of cognitive style for it to be a useful term both academically and in practice is that it must reliably identify individual differences among people and that these differences must remain relatively constant as a function of time.

There have been many different types of cognitive style discussed (e.g., analytic vs. relational, serialist vs. holist, field dependent vs. field independent, visualizer vs. verbalizer, etc.). Dansereau, Actkinson, Long, and McDonald (1974) present an extensive review of the current literature on cognitive styles within their discussion of learning strategies. The application of cognitive style categorizations to learning, retention, and transfer is of primary importance to this study. Pask (1976) found that whether a student's own learning (cognitive) style is matched or mismatched to a teaching strategy can have a large effect on his learning performance.

One of the types of cognitive style that has received a large amount of attention is that of mental imagery. Discussions of mental imagery have persisted for centuries, primarily in the discipline of philosophy. Although Fechner discussed his experimental investigations of imagery in his book, Elemente der Psychophysik, in 1860, the first quantitative discussion of mental imagery was that of Galton in 1880. Galton's work was the first attempt to arrive at a metric for assessing imagery. In 1909 Betts published a 100 page report involving twelve experiments on voluntary and spontaneous imagery. With the advent of behaviorism, the study of such things as mental imagery was not extensive. However, during the 1930's and 1940's there were a few studies of imagery, particularly evaluating its relationship to intelligence. For example, Brower (1947) investigated the relationship of imagery and intelligence (Otis Intelligence Test) and did not find a significant correlation. This is consistent with Carey's (1915) results with school children. In addition to the fact that the results of neither study were statistically significant, Carey's correlation was negative and Brower's was positive. A study by Davis (1932) also indicated a low correlation between imagery vividness and general intelligence (Army Alpha Intelligence Test). A study conducted by Bowers (1935) indicated that there is no consistent relationship of imagery ability and reasoning ability.

One of the problems with studying mental imagery at that point was that the meaning of the term was not very well defined. Friedman (1953) illustrated this problem with his statement that "Imagery has come to mean all things to all men" (p. 25). Holt (1964) discusses the definitional problem and the need for a taxonomy in his article, "The Return of the Ostracized." A dictionary definition that provides a reasonable starting point is from Funk and Wagnall's dictionary. This definition of image is "a mental representation of something, not perceived at the moment through the senses, including the accompanying emotion."

Within the last decade there has been a resurgence of interest in mental imagery. For example, five books written specifically on imagery were published within three years; Richardson (1969), Horowitz (1970), Segal (1971), Paivio (1971), and Sheehan (1972). Even with the upsurge in interest in imagery, the definitional problem still existed to some extent. The term "mental imagery" was often restricted to visual imagery rather than including the other "sensory" modalities. Pylyshyn (1973 expressed this concern in that he felt that a "picture metaphor" is seriously misleading.

There is inconsistency within the literature as to the relative dominance of various modalities of imagery. For example, Lindauer (1969) found that tactual and gustatory imagery were "superior" (i.e., more vivid) to visual imagery. This result is inconsistent with Brower's (1947) results which indicated that visual imagery was most frequent. Leibovitz, London, Cooper, and Hart's (1972) data agree with Browers indicating visual imagery was predominant. Leibovitz et al. also concluded from their study using factor analysis that imagery is not a general trait and that people have a definite tendency to use one modality more than others. This finding is inconsistent with the work of Betts (1909), Raju (1946), and Sheehan (1966a) in which they found that if imagery was good in one modality it was also good in the other modalities. One problem in comparing the results of these studies is that Leibovitz et al. investigated frequency of choice among the modalities; whereas Betts and Sheehan investigated the vividness of imagery across modalities.

The study of mental imagery has been plagued with methodological problems and ad hoc hypotheses. However, the construct itself has been effectively used in both theory and practice. The next part of this section will address the usefulness of mental imagery as a cognitive style. To be useful in any practical sense, there must be detectable differences among people as to their imagery, and the differences must be stable over time.

Physiological Correlates of Mental Imagery. There are many areas within the research literature that impinge upon the usefulness of the mental imagery concept. This literature resides in both the scientific and clinical medicine fields. Recent evidence as to the different functional roles of the two hemispheres of the brain and individual differences with respect to hemisphere dominance are examples of combined clinical and scientific contributions. The two hemispheres of the brain are anatomically separate entities with the corpus callosum interconnecting the left and the right brain.

Four major methods have been used to investigate the specialization of function between the hemispheres. The first method involves the study of unilaterally brain-damaged patients. The second uses patients who have had the major neural connections severed (commissurotomy) between the two hemispheres in order to control epilepsy. The third method uses normal subjects and presents stimuli such that they are "processed" on one side of the brain or the other. For example, visual stimuli can be presented to the left side of the visual field of both eyes such that the stimuli are "processed" by the right hemisphere. The fourth method involves electroencephelographic (EEG) recordings of the cortex while a normal subject is processing different types of information. The results of experiments using these methods all indicate that the two hemispheres are functionally specialized (Gazzaniga, 1967, 1975; McNeil and Hamre, 1974; Rigney and Lutz, 1975; Sperry, 1973). The primary functional distinction between the hemispheres is that the left hemisphere is the locus of language and the right hemisphere is the locus of spatial abilities (Gazzaniga and Hillyard, 1971; Pines, 1973; Seamon and Gazzaniga, 1972). Nebes (1974) conducted a study of commissurotomized patients that illustrated that the right hemisphere can recognize words and can cause words to be copied but cannot "verbally" label words. On the other hand, the right hemisphere is superior in spatial relationships and part-whole relationships (stimulus completion from fragmented data). Nebes refers to the right hemisphere being analog rather than propositional in nature. Kimura (1973) used dichotic listening and dioptic vision to investigate hemispheric dominance. The results indicate that the right hemisphere is dominant for music and visual perception, whereas the left is dominant for speech perception. Geschwind (1972) also found anatomical differences between the hemispheres which support the physiological and behavioral data. Calloway and Harris (1974) used EEG recordings to experimentally investigate hemisphere specificity for different stimuli. They found a shift in EEG as a function of whether the stimulus was a picture, music or written text. The music and pictures elicited more EEG activity from the right hemisphere, whereas the text resulted in more activity in the left hemisphere EEG.

The idea that the two hemispheres have a specialization as to the type of information they process is well established. There is also evidence that individuals have a tendency to have one or the other hemisphere dominant when information is processed and encoded (Bogen, 1975). Geschwind's (1972) anatomical studies support this.

The next obvious question is where does mental imagery reside, in the left or the right hemisphere, or both? For example, is visual imagery of the "same nature" as visual perception and, if so, is it processed by the right hemisphere? Hebb (1949, 1968) discusses imagery in the context of "cell assemblies." His contention is that first order cell assemblies are the basis of vivid specific imagery and that higher order assemblies are the basis of non-representational conceptual processes. If this is the case, then imagery should reside in the right side of the brain.

The majority of the experimental research involving the physiological correlates of imagery have involved EEG recordings. Golla, Hutton, and Walter (1943) conducted the first study of visual imagery using EEG. They found that an individual's mode of thinking is related to his occipital EEG. The nonverbal visual imager had a lower alpha wave, whereas habitual verbal thinking correlated with a persistent alpha wave. Golla et al. classified people into three groups: M--predominant visual imagery in thinking, P--predominant auditory/kinesthetic imagery, R--both. Short

(1953) found that he could discriminate between imagers and verbalizers on the basis of alpha blocking. In addition, he found that the imagers breathed more regularly relative to the verbalizers. Chowdhury and Vernon (1964) and Rimm and Bottrell (1969) supported Short's result that imager's breathing is more regular than that of verbalizers.

Slatter (1960) classified people in terms of imagery by using the EEG alpha wave amplitude, rhythmicity, and blocking. Many studies have supported these findings that imagery vividness could be evaluated on the basis of alpha wave amplitude and blocking (Costello and MacGregor, 1957; Drewes, 1958; and Stewart, Smith, and MacFarlane, 1959). Other studies have found results inconsistent with the former studies. Barratt (1956), for example, found that, although there was a slightly greater occipital EEG when the subject was imaging rather than verbalizing a problem, the technique was not a good discriminator among people. Drever (1958) also found it difficult to predict visual imagery from EEG recordings. Oswald (1957) concluded that the association between alpha blocking and visual imagery could have arisen out of the "difficulty of thinking" rather than the locus of imagery processing. Simpson, Paivio, and Rogers (1967) also discuss the methodological problems in the EEG literature. The most serious problem with the previous studies was the ad hoc methods used to assess imagery. Simpson et al. used both an objective performance test and a subjective rating scale to assess imagery capability. In addition, during the EEG tests, they utilized a double blind procedure wherein the experimenters did not know to which group (high or low imagery) the subjects belonged.

There have also been studies of eye movements coincident with visual imagery of stationary and moving "stimuli" (Ornstein, 1974; Zikmund, 1966, 1972). These studies have found that there is oculomotor activity during imaging.

The results of the physiological studies of imagery illustrate that there is a large amount of support for a two system approach to information processing. One of the systems processes spatial/abstract material; the other system processes verbal/analytical material. The physiolocical results also indicate that, to some extent, people can be categorized as imagers or non-imagers (usually referred to as verbalizers) on the basis of physiological indices. However, as with essentially all areas in which behavior attributes are predicted on the basis of physiological measures, the room for methodological errors and misinterpretation is great. That is, when one is working with a construct as vague as mental imagery (being introspective in nature) and is trying to correlate it with a low signal in a high noise background such as the EEG activity, the experimental control must be extremely rigorous. Neither of these factors tends to lead to high predictive validity with respect to performance.

Behavioral Assessment of Mental Imagery. There are many methods by which imagery has been investigated using behavioral performance data. These have ranged from tests that correlate self-reported imagery ability and recall or reproduction performance (Davis, 1932; and Sheehan, 1966a), to correlating imagery with clairvoyance and card guessing performance (Honorton, Tierney, and Torres, 1974). There is an extensive amount of literature that indicates that there are reliable individual differences among people with respect to their vividness of imagery (DiVesta and Ross, 1971; Madrid, 1972; Marks, 1972; and Paivio and Ernest, 1971).

A problem with this literature, as with that presented in the previous section, is that of the definition of mental imagery. The majority of the work on individual differences has focused on visual imagery. The terms that are often used to categorize individuals as high in visual imagery are visualizers and pictorializers. For example, in a study on visual imagery, Madrid (1972) divided people into vivid and poor visualizers. He found that the vivid visualizers (imagers) had a higher accuracy of recall on a picture memory task. Morelli and Lang (1971) used a test of imagery entitled the Betts Questionnaire Upon Mental Imagery (Betts 1909, discussed in the next section) and referred to the individuals that were high visual imagers as "picturalizers."

These studies illustrated that individuals did differ in terms of their performance on the imagery tests and that the differences were consistent with their performance on other performance tests. A dichotomy that is used in the individual differences literature pertaining to imagery is that of imagers (particularly visual imagers, visualizers, pictorializers) versus verbalizers (Bernstein and Gonzalez, 1971; and Morelli and Lang, 1971). Individuals that are "low" imagers tend to be more verbal/symbolic in nature than do "high" imagers.

An area of investigation that has provided a significant amount of support for this contention is human memory. There have been a number of studies (of both long and short term memory) that have indicated that there are two memory codes, one being analog (e.g., visual or imagery) and one being more symbolic (e.g., verbal or mathematical). Wallach and Averback (1955) proposed a two mode-memory system that included imagery and verbal, with rich interconnections between the two. Underwood (1969) also presented a multidimensional approach in which one of the attributes was associative nonverbal (mental imagery), and another was associative verbal. Some of the work addressed spatial (visual) and verbal coding with no direct implication of mental imagery (Bahrick and Boucher, 1968; Brooks, 1968; and Salthouse, 1975). These studies illustrated the possibility of two modes on the basis of memory interference (spatial/spatial and verbal/verbal more than spatial/verbal).

Paivio and his co-workers (Paivio, 1971; Paivio and Begg, 1974; Paivio and Csapo, 1969, 1971) conducted a series of memory experiments that specifically investigated imagery encoding and verbal/symbolic encoding. Their research strongly supported the idea of a dual-coding memory mechanism, one being imagery (analog) based and the other being symbolic (propositional). In fact, Paivio and Csapo (1973) found that the two modes are additive in that showing both a picture and the corresponding word resulted in better recall than either one presented twice. Other researchers conducting memory interference research during the same time period also supported Paivio's contention of a dual encoding mechanism (Byrne, 1974; Elliott, O., 1971; Elliott, L., 1973). Bower (1972), in a review discussion of imagery and associative learning, states that "The function of memory imagery is to put us in direct contact with 'how' things looked, or sounded, or felt, or tasted, as distinct from 'what' they resembled, what they sounded like, looked like, felt, or tasted like" (p. 52).

This research indicates that there are two mechanisms that have potential use in memory. However, it does not necessarily support the idea that some individuals are primarily imagers and others are primarily symbolically oriented. In fact, fifty years ago Griffitts (1927) criticized researchers for using the phrase "imagery types" when the distribution of imagery vividness is relatively normal. It is totally possible that individuals that are high imagers are also high verbalizers. If this were the case, then it would be expected that the "high" individuals would tend to have higher intelligence. However, as was discussed in a previous section, the correlation between imagery ability and intelligence appears to be extremely low. Therefore, this would indicate that an individual with vivid imagery could be low in propositional ability.

Whether people can actually be classified as high imagers versus high symbolics (verbalizers) or simply high vs. low imagers is yet unanswered. It is known, however, that the vividness of imagery can be reliably measured and that there are relatively stable individual differences among people along a vividness continuum. The next section discusses the methods most often used to assess mental imagery and the studies that have evaluated the reliability of those methods.

Measurement of Imagery Vividness and Control

In addition to the physiological and performance methods of assessing mental imagery previously discussed, self-report (self-rating) methods have also been used (Davis, 1932; and Rimm, 1969). The first well developed self-rating test was the Betts Questionnaire upon Mental Imagery (QMI, Betts, 1909). This test required the individual to rate his images in terms of seven degrees of clearness and vividness. The rating scale is as follows:

1. Perfectly clear and as vivid as the actual experience.
2. Very clear and comparable in vividness to the actual experience.
3. Moderately clear and vivid.
4. Not clear or vivid but recognizable.
5. Vague and dim.
6. So vague and dim as to be hardly discernible.
7. No image present at all, you only "know" that you are thinking of the object.

The various attributes of imagery that were assessed were: (1) visual imagery (e.g., shape, size, distance, color and movement), (2) auditory imagery (e.g., loudness and pitch), (3) cutaneous imagery, (4) kinesthetic imagery, (5) gustatory imagery, (6) olfactory imagery and (7) organic imagery (e.g., hunger, fatigue, and thirst).

The Betts QMI test was the predominant method of assessing mental imagery until 1967. Sheehan (1967a) conducted a factor analytic study of the Betts QMI in an attempt to shorten the test administration time. Sheehan found that the 150-item QMI could be reduced to a 35-item questionnaire. The resultant cross validation correlation was 0.92 between the total scores based upon the complete scale and the shortened form. A subsequent cross-validation performed by Sheehan (1967a, 1967b) on 60 subjects showed a correlation of 0.98 between the long and short form. The short form required 10 to 15 minutes to administer.

Subsequent studies have evaluated the reliability of the Sheehan short form of Betts QMI. Sheehan (1967b) found a test-retest correlation of 0.78 for the short form administered with a seven month interval between tests. Evans and Kamemoto (1973) observed a somewhat higher correlation of 0.91 in a test-retest study over a six week period. In an attempt to eliminate temporal characteristics, Juhasz (1972) performed an odd-even test on the short form and found a reliability of 0.95 (Cronbach's a_2 coefficient). Although these estimates of the short form's reliability vary to some degree, they are, as Evans and Kamemoto put it, "high for a questionnaire on such an emphemeral property as vividness of imagery" (p. 282).

It can be concluded that the Betts QMI and the Sheehan's short form of Betts QMI are internally reliable and are relatively stable over time. However, there is evidence that the test is not culturally unbiased. Marsella and Quijano (1974) found that the Betts test (Sheehan's short form) is better suited for western culture. Sheehan (1967a) in a study of imagery vividness of Australian and American college students, found that the American subjects were more vivid imagers than the Australian subjects. However, Marsella and Quijano's findings indicate that the difference may be due to the characteristics of the test rather than the imagery characteristics of the two groups.

Another test of mental imagery that has received less attention than the vividness tests is that of the Gordon test of imagery control.

Essentially, the vividness tests ask how well you can "imagine" an item, whereas the Gordon (1949, 1950) test evaluates the ease with which people can control and manipulate images. The Gordon test is concerned only with visual imagery. In an odd-even test of internal reliability of the Gordon test, Juhasz found the reliability to be 0.88 (Cronbach's a_2 coefficient). There have been no test-retest reliability studies of the temporal characteristics of the Gordon test.

The literature discussed in the present section illustrates that there are reliable, easily administered tests of mental imagery. The literature presented in the previous sections indicates that there are individual differences among people in their use of mental imagery. In fact, many of the studies dichotomized people into high imagers and low imagers. The problem arises, however, as to where the criterion (e.g., on a score such as the shortened Betts QMI) should be set to differentiate between these "groups."

The original data collected by Betts (1909) on the distribution of imagery illustrates that there is a problem with discussing the imagery groups. Referring back to the seven point scale of the Betts test the proportion of responses in the various categories is as follows:

1. Perfectly clear - 20%
2. Very clear - 32%
3. Moderately clear - 23%
4. Not Clear - 13%
5. Vague and dim - 7%
6. Hardly discernible - 3%
7. No image - 2%

The distribution appears to be skewed but is definitely not bimodal. In fact, the median "level of imagery vividness" appears to be at the top of the "very clear" range. This does not support the dichotomy of high vs. low imagers in terms of "imagery types" (Griffitts, 1927). An approach taken by some of the studies involving high and low imagers is that of a high selection ratio. That is, many people were pretested and those at the two relative extremes of the distribution were chosen as subjects. For example, Sheehan and Neisser (1969) selected individuals that had a mean rating of 1.86 or lower (high imagers) or 3.54 or higher (low imagers) in their study of the effect of imagery on recall. Sheehan (1971) used a criterion of less than 2.0 (high imagers) and greater than 3.0 (low imagers) in a study of imagery and incidental learning. Although this type of a procedure is appropriate to define high and low imagery groups, the applicability of the results to the actual population must be considered limited.

The results of these studies do illustrate that there are differences in performance as a function of imagery in the extremes, but do not indicate the robustness of the effect in the midrange. The literature discussed in the next section describes the effect of imagery on such things as learning and retention performance. However, it should be remembered that, in many cases, the subjects are not randomly selected from the population at large, but rather, are selected from the population of high and low imagers.

Mental Imagery in Learning and Retention

The literature presented in the previous sections illustrates that there are differences among people in terms of mental imagery vividness and control, and that these differences can be reliably measured quantitatively. The present section addresses how the imagery differences can be utilized in the area of learning and retention.

One of the first experimental studies that indicated that imagery vividness had an effect on learning and retention was conducted by Bowers (1932). He found that higher imagers (determined by self-rating on the stimuli used) retained somewhat better than low imagers over a 3-day retention interval. However, this was the case for only visual and kinesthetic imagery (and stimuli); auditory imagery (and stimuli) ability had no effect. At about the same time, Jenkin (1935) concluded that, although imagery played a part in recall of specific items, concepts were formed through words.

One of the primary indications that imagery might be important in learning and retention was the previously discussed literature on imagery as one of two memory encoding systems. Much of this work was concerned exclusively with verbal learning although some studies did attempt to extrapolate to the areas of concept learning and motor learning. Imagery began to receive a lot of attention in the popular literature in that it was utilized in many mnemonic based memory systems (Yates, 1966).

A definition of imagery specifically applied to a learning and retention context is given by Bernstein and Gonzalez (1971a): "Imagery, as related to retention, denotes the use of visual mental representations of relatively concrete objects as mediators for storage" (p. 6). This definition, however, suffers from the constraint of including only visual imagery. A more encompassing definition should also make provision for auditory, kinesthetic, tactile imagery, etc. This is particularly the case when considering mental imagery in the context of continuous perceptual-motor or procedure following tasks.

Rigney and Lutz (1974, 1975) discussed the literature on the different "internal representational systems" and their impact on the leaning and retention of conceptual information. Their particular interest was in using computer graphics (in a computer assisted instructional system) to maximize the utilization of imagery encoding.

Sheehan (1967c) was one of the first investigators to study the properties of mental imagery that facilitated learning and retention. He concluded that the "organizational" aspect of imagery is the property that is relevant to retention. A study by Morris and Stevens (1974) support Sheehan's conclusion in that they found that imagery is only facilitative when the images link (associate) items together. Dansereau, Long, McDonald, Actkinson, Collins, Evans, Ellis, and Williams (1975) utilized this "associative" property in a training program. The program used what Dansereau, et. al. referred to as "connective" images to progress students through increasing complexity in academic lessons. Paivio (1969, 1972) and Paivio and Smythe (1971) found that the concreteness of an item affected its image-evoking value and is an important aspect of imagery in learning and retention. In addition, they found that meaningfulness is of less importance in imagery encoding relative to its importance in verbal (semantic) encoding.

In a study of paired-associate learning, Bower (1970) found that imagery enhanced paired-associate learning without increasing the stimulus recognition. These results indicate that imagery is important to the relational associating of items, rather than to stimulus encoding (stimulus differentiation). This is somewhat inconsistent with the results found by Gronninger (1974) that imagery is important during acquisition (encoding) rather than during recall. A possible explanation of the inconsistency among the conclusions of these studies is indicated by the results of a study conducted by Smith, Barresi, and Gross (1971). They found that, using imagery or repetition instructions, visual imagery was effective in long term memory (referred to by Smith et al. as secondary memory) but not effective in short term memory (referred to as primary memory). Therefore, depending on the time frame of a retention study, imagery effectiveness could be interpreted differently.

It must be remembered that, although the context of the present study is perceptual-motor procedure following behavior, the majority of the studies cited in this section were dealing with either conceptually oriented verbal material or abstract visual patterns. The generalization of conclusions from one context to the other must be done with caution. In a review of the learning and retention research in the verbal area, Fox (1971) attempts to integrate and contrast the verbal learning data and "motor procedures."

An area of investigation that somewhat bridges the gap between mental imagery in abstract learning and motor performance is that of mental practice of perceptual-motor skills. Richardson (1967) provides a good review of the literature on mental practice up to a decade ago. However, there have been interesting results obtained since his review article.

Perry (1939) was one of the first researchers to experiment with mental practice of motor tasks. He found that there was a positive effect of mental practice. An interesting observation made by Perry, is that many more practice trials can occur, during mental practice relative to physical practice, per unit of time.

A number of other, more recent, studies have indicated that mental practice is effective in various types of tasks (Hackler, 1972; Samuels, 1970; Twining, 1949). These studies have ranged from improving reading skills (Koziey and Bauer, 1972) to complex motor skills, such as shooting foul shots in basketball (Clark, 1960). However, a number of studies have found contradictory results in that mental practice was not effective for similar tasks (Conly, 1969; Corbin, 1966; Goldman, 1972; Willis, 1967).

It is interesting to note where both the positive and the negative results on mental practice reside in the literature. The positive results reside in the open technical literature (e.g., journals published by the professional societies). The negative results are not in the open literature and are only presented in unpublished theses and dissertations. It appears that the system for acceptance into the technical literature (generally, probability of α error < 0.05) is serving as an effective filter that can (and has in the case of mental practice) led to very misleading information and incorrect conclusions.

Another area of concern in evaluating the results of the studies discussed in this section is their relationship to actual education and training. Fox (1971) in his discussion of verbal versus motor learning research, concludes that, although there exists a problem relating verbal and motor learning, the more serious problem resides in transferring from laboratory studies to the "real world" situations.

A study performed by Prather (1973) is an example of applying mental practice to an operational problem. He investigated the use of mental practice in learning to land a T-37 aircraft. The experimental group in Prather's experiment listened to a verbal (tape recording) description of the landing process whereas the control group did not. The experimental group was to imagine themselves going through the process. His results indicated that the introduction of mental practice was effective. However, a problem with a study such as this one is that it is very difficult to control for the amount of information given to the experimental and control groups. That is, it could be that the primary influence of the imagined trial was the additional information provided by the tape recording, rather the practice alone.

The problems of interpretation of the data and possibilities for extraneous confounding of the data in the areas of mental imagery and mental practice in learning and retention are severe. This is particularly the case when extrapolating from one type of task (e.g., verbal learning and retention) to another (e.g., perceptual-motor procedure following learning and retention). The next section discusses the literature on learning, retention, and transfer of procedure following tasks, and research that relates to this area.

Learning and Retention of Procedural Tasks

There has been an extensive amount of work conducted in the area of learning, retention, and transfer of skills. Naylor and Briggs (1961) present a very good review of the literature on the long-term retention of skills to that date. One of the primary contributions of that review was to classify and describe the types of variables in retention research. They discuss four categories of variables: (1) task variables (e.g., task length, complexity, speed requirements), (2) learning variables (e.g., distribution of practice, massed or spaced), (3) retention variables (e.g., verbal and imagery practice, interference tasks), and (4) recall variables (e.g., warm-up, recall environment). Naylor and Briggs discuss some of the interactions between these variables. The point is brought out that a researcher cannot investigate only one or two types of variables without considering the influence of the other types on the interpretation of his results. Other attempts to review and organize the literature are presented by Bilodeau (1966) and Ginsberg, McCullers, Merryman, Thomson, and Witte (1966). Blaiwes and Regan (1970) categorize the research on learning, retention and transfer in the context of applying the integrated results to training device research and development. Bernstein and Gonzalez (1971) edited the proceedings of a conference on learning, retention, and transfer at which the most active researchers in the field presented the issues and potential solutions.

A very good review and annotated bibliography of the retention area was provided by Gardin and Sitterly (1972). One of their major conclusions was that "It seems clear that the literature has identified the level of performance on the final training period as the primary prediction of skill retention for any given retention interval duration" (p. 20). This relationship, along with the fact that there is a distinct effect on performance as a function of the retention interval, to a large extent sums up our knowledge of skill retention. The disturbing aspect of this state of knowledge is that the initial research conducted in the late 1950's left little doubt as to these effects (Ammons, Farr, Bloch, Newmann, Day, Marion, and Ammons, 1958; Hammerton, 1963; and Newmann and Ammons, 1957). In addition, although statistically significant experimental results lead to more secure conclusions, what the scientific community knows about retention is about the same as what the "man on the street" knows; we can't remember what we didn't learn and we forget over time.

Related to these two conclusions about retention, there is one interesting impression given by the literature. It has been found in many experiments and is discussed in many review papers that procedural tasks result in less retention than continuous motor tasks (Ammons, et al, 1958; Gardin and Sittenley, 1972; Naylor and Briggs, 1961; and Sitterley, Zaitzeff, and Berg, 1972). That is, complex continuous tracking skills are retained relatively well for a long duration (at least 24 months, Fleichman and Parker, 1962); however, procedural tasks are very poorly retained (Hufford and Adams, 1961; Mengelkoch, Adams, and Gainer, 1960, 1971). One method that has been found to be effective in reducing forgetting is to practice (rehearse) the task during the retention interval (Brown, Briggs, and Naylor, 1963; Macek, Vilter and Stabbs, 1965; and Naylor and Briggs, 1963).

One of the problems with comparing the retention of procedural (usually discrete) tasks and continuous control tasks is equating the two in terms of difficulty. As discussed by Naylor and Briggs (1961) and Briggs (1971), there is no mutual method by which you can quantify the difficulty of performing the two tasks. In addition, Briggs (1971) criticizes the research literature in terms of its use of "open-loop" procedures rather than the more appropriate "closed-loop" procedural tasks that occur in real operational tasks. Bernstein and Gonzalez (1971) discuss this problem in that they contend that the tasks used in laboratory experiments do not have the inherent organization of "real life" tasks. The problem resides in the fact that most researchers have been focusing upon the learning, retention, and recall variables and have been spending much less time making sure that the task variables are handled appropriately.

In summary, it is relatively well documented that procedural tasks are highly prone to forgetting within a relatively short time. It can also be concluded that forgetting is a function of time and a function of a number of factors in effect during training, during the retention interval, and at the time of recall. The next section focuses on one of the primary factors involved in the training phase, the equipment used to train procedural tasks.

Training Devices and Procedural Training and Transfer

In the past few years there has been a rapidly growing interest in the characteristics of training devices that lead to effective training and high-positive transfer of training to the operational equipment. The literature pertaining to this area resides primarily in technical reports and proceedings of technical meetings rather than in technical journals. The phrase that has become popular in defining this area is "trainer (or simulator) fidelity requirements." Fidelity, in this case, is a close synonym of "realism."

The majority of the interest has focused upon the more complex mission requirements from a perceptual-motor standpoint rather than on procedural tasks. However, as the introduction of this report discussed, the procedural aspect of the human operator's job is increasing in both frequency and importance. The one thing that is evident from the many reports addressing the fidelity issue is that fidelity is not the only concern and may, in fact, not be the main concern. Micheli (1972) in a good discussion of the research trends in the area of fidelity of simulation for training use concludes: "It is contended by the present report that training effectiveness is more a function of the manner in which the trainer is used than of the fidelity of the trainer" (p. 21). Caro (1976, 1977) recently discussed some of the implications of trainer utilization in the military environment.

In a study specifically investigating a procedural task (aircraft cockpit procedures), Prophet and Boyd (1970) concluded that high complexity (fidelity) is not necessary for high transfer of training from a training device to the operational equipment. These results were supported by a study conducted by Sitterley and Berge (1972) which looked at static and dynamic methods of rehearsing emergency procedures in a simulated space flight task. They found that the static methods of training procedures were effective. Sitterley (1974), in a second experiment confirmed that dynamics are not necessary for retraining of a task after a long non-practice interval. In fact, his study indicated that a properly structured open-loop method of simulation is feasible even for a control task.

A series of studies conducted by the Human Resources Research Office investigated the closed-loop versus open-loop aspect of training devices for procedural tasks. Cox, Wood, Boren, and Thorne (1965) used ten devices that ranged from a hot-panel (high fidelity simulation of the operational equipment), through a cold-panel (same as the hot panel but without interactive display indications), to a drawing of the equipment. The results of their study did not indicate any differences in training time on the various panels. Grimsley (1969a, 1969b) investigated the relative effectiveness of a hot panel, a cold panel and a reproduction of the panel in terms of training time, transfer (to the hot panel), and retention over a four week period and a subsequent 18 day period. His results supported those of Cox, et al, and extended them to the retention situation, finding no difference in training time, retention, or retraining time. In addition he found no indication of a transfer problem from either the cold panel or the reproduction to the hot panel. Mirabella and Wheaton (1974) conducted a similar experiment with hot panel, cold panel and pictoral representation. Their results indicated that the cold panel was the worst with the hot panel and picture not significantly different in terms of acquisition. These studies illustrate that low fidelity (with a resulting low cost) can be effective in the training of procedure-following tasks.

There are two primary aspects of device fidelity in terms of procedural training devices. First, there is the cueing of the trainee. That is, if the trainee cannot remember the exact setting at which a gauge should be set, the range and graduations on the display gauge can cue (prompt) him. In the same sense, seeing the resultant effect of one action can cue the trainee as to the next action in a sequence.

The second category of information involves feedback to the trainee as to the result (and possibly the correctness) of his action. In this case, for example, performing an action in the correct order may result in a display indication that signals that the action was correct. Although in some situations these two categories are difficult to separate (e.g., a signal can be both feedback as to the previous action and a cue to the next), they have different implications for a training device. The cueing characteristic often requires an active console (e.g., preprogrammed or instructor operated). However, the feedback characteristics often requires an active and interactive capability. That is, the equipment must respond differently depending upon the trainee's inputs. This branching type of logic has important cost implications.

The present study is designed to investigate alternative approaches to procedure training devices that utilize mental imagery in providing the cueing and feedback to the trainee. The next section summarizes the research findings discussed in this and the previous sections and indicates the implications of those findings for the present study.

Summary of the Research Findings and Their Implications for the Present Study

The research literature presented in the previous sections has ranged in topics from the hypothetical construct of "mental imagery" to the very practical concerns of training device design and cost. The goal of this study is to utilize what is known about the human's memory system and apply it in the effective design of training devices for procedural tasks.

Summary of Research. Although the conclusions drawn from the research literature are, at times, inconsistent, and the methodological problems are severe, a number of points can be made with confidence.

1. Individuals do vary in their preferred modes of processing information and these modes can be referred to as cognitive styles.
2. The matching of individual cognitive style and training strategy is beneficial (for particular tasks).
3. There are both physiological and behavioral indications that individuals differ in their use of mental imagery and that it is a meaningful and potentially useful aspect of cognitive style.
4. Mental imagery can be reliably "measured" with the Betts QMI and the ratings on the QMI are related to other performances in a consistent manner.
5. Mental imagery plays a role in learning and retention in that it appears to be one means of encoding and/or storing information in memory.
6. Procedural tasks are becoming more predominant in the human

operator's job, but the information base related to the human's capability to learn and remember procedures is limited.

7. Training devices for procedural tasks need not be of high fidelity indicating that the human can replace the cueing and feedback usually presented by devices with information stored in memory.

Purpose of the Present Study. The purpose of this study was to investigate the effectiveness of visual imagery techniques as they pertain to initial training, retention, and transfer of training. In addition to investigating the relative merit of using visual imagery versus conventional training methods, the possibility of matching instructional strategy and the trainee's cognitive style was investigated. The particular task used in the study was representative of the many sequential procedures performed which range from operating master control panels in industrial plants to normal and emergency procedures in air vehicles. The next section describes the experimental task, training devices, and procedures used in the study. Two experimental training strategies were developed which provided the trainees with different amounts of cueing and feedback.

METHOD

Original Learning and Transfer Tasks

As was discussed in the Introduction, one of the primary criticisms of the research literature on training and retention is that the experimental tasks used have no correspondence to "real world" situations. This has two implications; first, the results are often difficult to generalize to operational training situations, and second, the face validity of the experiment to the subjects is low. That is, an abstract task that has no meaningfulness to the subjects is more likely to be treated as an experimental game between the subject and the experimenter. The meaningfulness of the task has an influence on both the motivation of the subjects during the experiment as well as imparting an inherent organization to the task that is important for retention.

The present study attempted to develop a realistic procedural task that would both be a valid reference point for operational training and would be meaningful to the subjects.

The operational task that the subjects initially learned to perform in the study involved a procedural sequence of simple actions. Each individual action was simple in that precise timing or coordination were not required. The difficulty in the task resided in the fact that it had to be performed, without a checklist, in the correct sequence with no significant hesitation between actions. The operational equipment is illustrated in Figure 1.

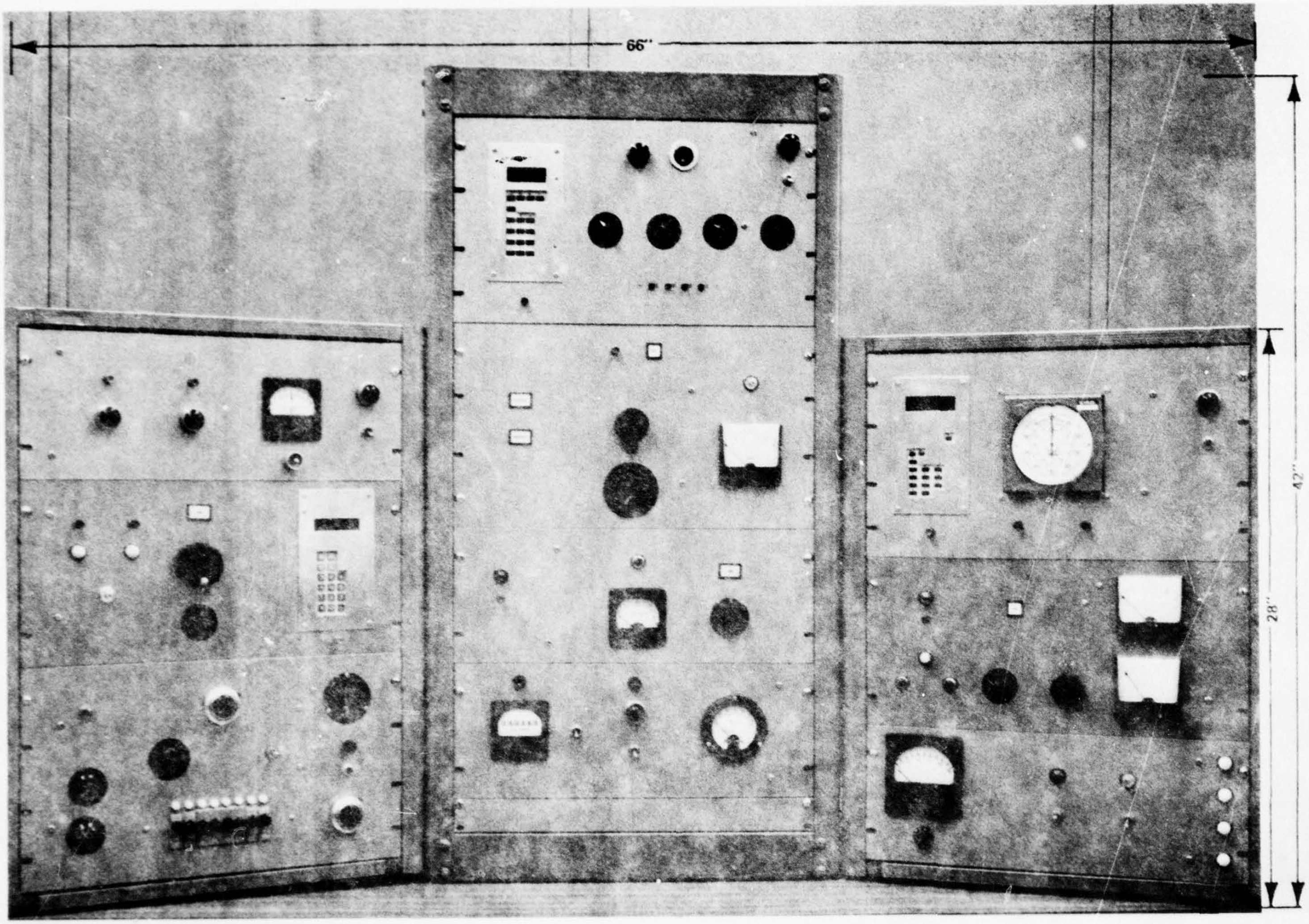


Figure 1 OPERATIONAL EQUIPMENT

The types of controls and displays used in the equipment included:

(1) toggle switches - both vertical and horizontal orientations

(2) rotary switches - both discrete and continuous settings

(3) levers - both vertical and horizontal orientations

(4) push-buttons - both singly and in keyboard arrays

The displays that were used included:

(1) lights - both on/off and color coded

(2) circular meters - simple meter movements

(3) linear meters - simple meter movements

(4) digital readouts - from one to five digits

The displays and controls making up the equipment were not labeled as to their functions.

The actual task scenario involved the process of setting up a conveyor line production operation. The general description of the task and a graphical representation (as it was presented to the subjects) is given in Figures 2 and 3 respectively. There were a total of 87 discrete steps involved in the task with 26 of the steps requiring the subject to set in a particular value or make a decision on a value. A listing of the sequential steps of the task is presented in Appendix A. This task sequence was a subset of a longer task (135 steps) that was concluded to be too difficult during preliminary studies.

The task of 87 steps, as it was structured, was made up of two levels of detail. The first level (macrostructure) involved twenty "chunks." A chunk involved a number of discrete steps (microstructure) that, You will be learning how to set up a production line that runs automatically after the initial set-up. The figure on the next page illustrates the production line. The components that are "processed" on the line are loaded on a conveyor, travel down the conveyor, and are taken off by a receiver. While the component is on the conveyor, a number of measurements are taken to ensure that it is within specified limits. Also, the components are coated with paint as they proceed down the conveyor. After the coating has been applied, the component is dried.

The general sequence of setting up the process is as follows:

1) Turn on the main power to the equipment.
2) Turn on the conveyor.
3) Turn on the loader.
4) Set up the measurement tools.
5) Check the measurements with a calibrated component.
6) Recalibrate the conveyor.
7) Turn on the drying equipment.
8) Set up the paint mixtures.
9) Turn on the receiver.
10) Match loader and receiver speeds.
11) Recalibrate the conveyor speed.
12) Put the process into operation.

Now we will step through the individual actions that must be performed in sequence. Although you should do the set-up procedure as quickly as possible, it is more important that you attempt to make no mistakes.

Figure 2. ORIGINAL LEARNING TASK AS DESCRIBED TO SUBJECTS

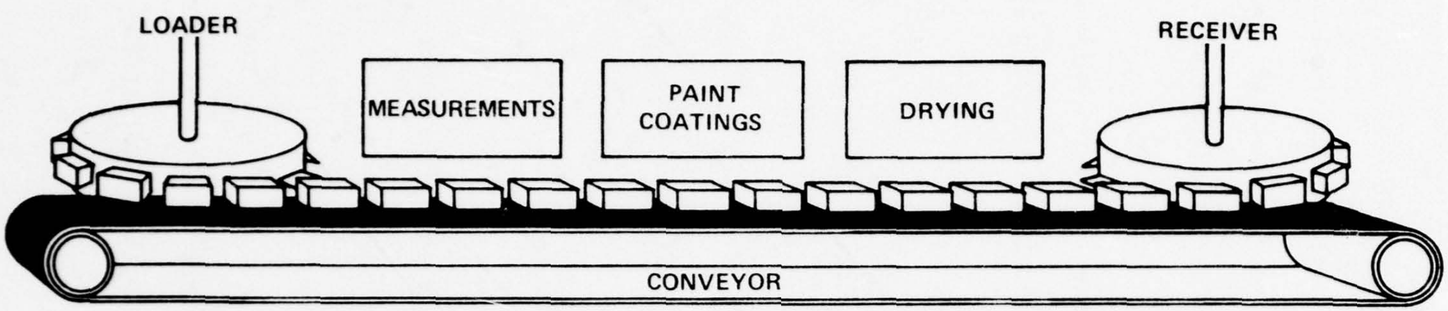


Figure 3 GRAPHICAL REPRESENTATION OF CONVEYER LINE

together, made up a larger action. For example, the chunk, "Turning on the loader," included: (1) presetting the loader speed control to zero, (2) setting the speed range switch to the 30-40 range, (3) switching on the power to the loader, and (4) setting the loader speed to 15 feet per minute. The order of the steps, both between and within the chunks, was a logical sequence in the process of setting up and checking out the process.

The transfer task consisted of 83 sequential steps and 24 numerical settings. This task was primarily a reordering of the chunks and individual steps within a chunk from the original learning task, with a few deletions and additions. The general description and listing of steps of the transfer task is provided in Appendix B.

Initial Training

The purpose of the study was to investigate three training devices that utilized different training strategies. This section describes those strategies. A schematic representation of the total procedure (initial training, retention, and transfer) is provided in Appendix C.

Conventional Practice Strategy. In the conventional strategy for training procedural tasks, the trainee repeatedly performs the exact behavior that he performs in the operational environment. This strategy requires the use of an interactive training device in which the controls and displays operate in a manner similar to the operational equipment. The learning of the procedural task involves the sequential chaining of stimuli and responses. That is, the final state of the previous action serves as an initiation cue for the next action, and so on. This sequential chaining is accomplished through performing the sequence, obtaining knowledge of errors (feedback), and reperforming the sequence until criterion (e.g., errorless) performance is attained.

The training sequence used for the conventional strategy began with illustrated instructions presented by the experimenter that explained the procedure to the trainee and established a contextual framework. The task was then demonstrated twice to the trainee on the operational equipment. The trainee then practiced the task until he performed the procedure at the criterion level (discussed in a later section). Errors consist of sequential misorderings, setting errors, and excessive inter-response intervals. During the practice trials, the trainee was stopped immediately upon committing an error. The feedback to the trainee involved the instructor (experimenter) reiterating the previous action, the correct present action, and the correct next action, as they appeared in the written instructions. After the trainee met the criterion, he performed one more trial referred to as the "proficiency confirmation trial."

The conventional strategy (i.e., control) involved the active participation of the trainee and included the same spatial and temporal relationships as those encountered when performing the operational task. In addition, recognition memory was possible in that the calibrations and numerical values were displayed on the equipment. This information could cue the trainee as to the correct actions. The experimental strategies, on the other hand, utilized different spatial and temporal relationships than those encountered in the operational tasks.

Reproduction Practice Strategy. In the reproduction strategy, the trainee reproduced the control actions and system responses using the medium of paper-and-pencil. A scaled photograph (35% scale) of the operational equipment (without calibrations or numerical values) was provided to the trainee. Figure 4 illustrates the pictorial representation of the operational equipment. This drawing was then modified by the trainee with a pencil to illustrate his control actions and the resulting system responses as he performed the procedural task. For example, the trainee indicated control actions by drawing arrows to illustrate the direction of the movement and lines to indicate the terminal position of the control or display indication. The depressing of a pushbutton was indicated by putting an X over the control. Illuminated lights were indicated by placing small lines radial to the light. As with the conventional strategy, learning utilizing this strategy involved the sequential chaining of stimuli and responses. The previous system responses remained visually accessible to the trainee by scanning the illustration.

The training sequence used for the reproduction strategy began with the same illustrated written instructions as those used for the conventional strategy. The task was then demonstrated to the trainee on the operational (test) equipment. This instruction was followed by a second demonstration of the procedure using the training device (paper and pencil). The trainee then practiced the task (using paper and pencil) until he performed the procedure at the criterion level. The manner of handling errors and providing feedback was the same for this strategy as for the conventional strategy. After performing the practice task to criterion,

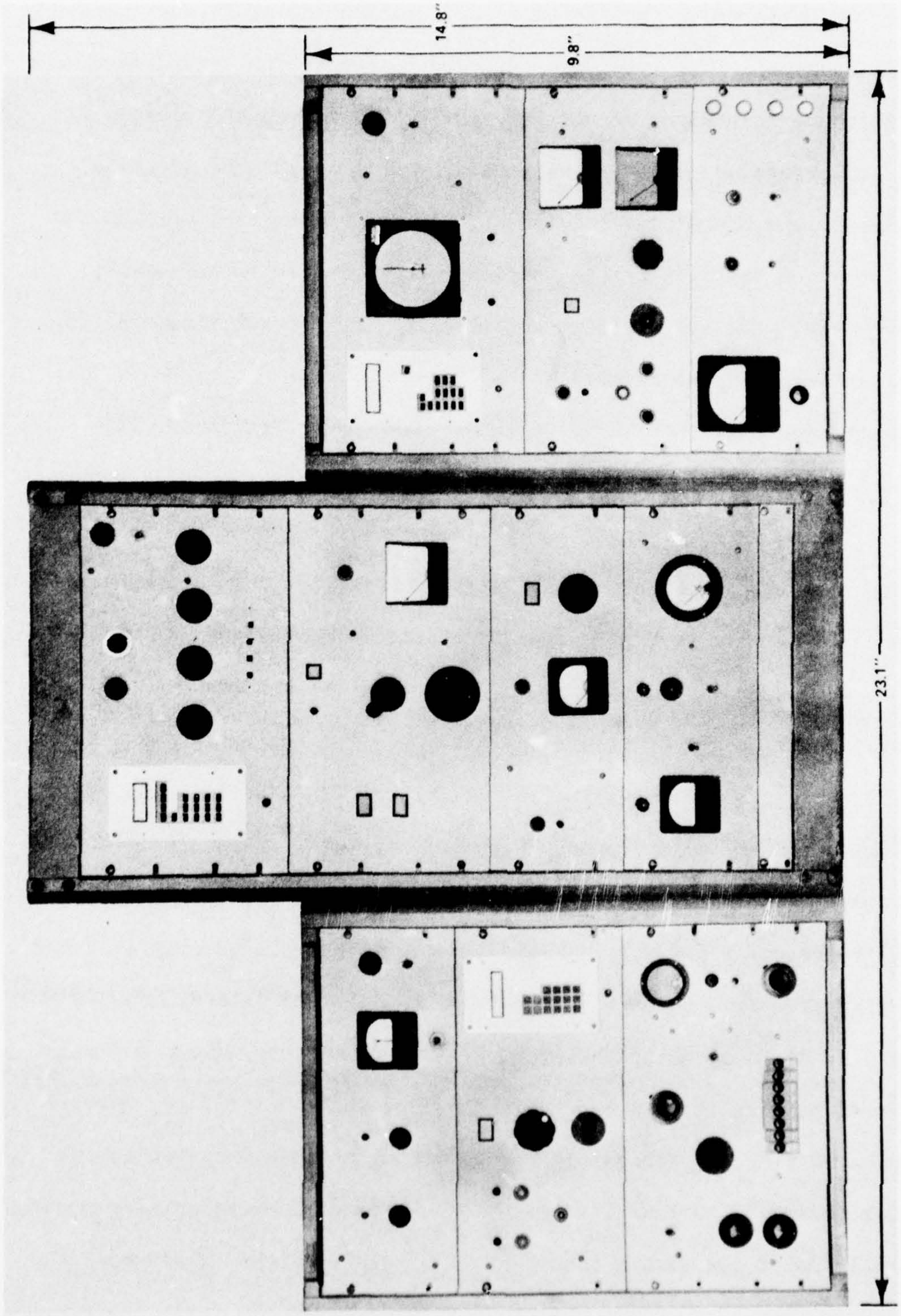


Figure 4 EXPERIMENTAL TRAINING DEVICE

the trainee performed a "proficiency confirmation" trial on the operational equipment. This trial was intended to ensure that any differences in performance that might be observed during the retention trials would be due to forgetting rather than transfer problems from the pictorial apparatus to the operational equipment. If the number of errors on the proficiency confirmation trial was two or more greater than the last training trial, the trainee then went back to the reproduction training device and practiced to criterion.

The reproduction strategy involved active participation of the trainee but without the exact spatial and temporal relationships experienced in the operational task. Recall memory was required in this strategy more than the conventional strategy, in that the calibrations and numerical values were not visually available to the trainee as cues. However, once he had responded by modifying the illustration, the visual presentation of previous actions was available for cueing the next action. This visual accessibility of the results of previous actions was the primary cue available in the reproduction strategy that was not available to the trainee in the next experimental strategy, blind practice.

Blind Practice Strategy. This strategy was designed such that the trainee was required to make more extensive use of his memory imagery capabilities in performing the procedural task. He reproduced the same motor responses as those produced in the reproduction strategy; however, there was no visually accessible record of the actions imparted to the training medium. The training medium consisted of a blind writing mechanism (ball point pen with a cover over the point) which did not mark the photograph. The trainee presumably actively "interacts" with the equipment through his utilization of imagery.

The training sequence for the imagery strategy paralleled the sequence for the reproduction strategy. The sequence was: (1) illustrated instructions describing the operational task, (2) demonstration on the operational equipment, (3) demonstration on the training medium, (4) practice on the training medium (with immediate feedback), and (5) performance of a "proficiency confirmation" trial on the operational equipment after meeting the criterion on the training device.

As with the reproduction strategy, this strategy involved the trainee's active participation although the spatial and temporal relationships are not identical (e.g., 35% scale, orientation to the body, etc.) to the operational task. In addition to active motor participation, this strategy is designed to require more active "perceptual" participation than either of the other two strategies. That is, for rehearsal of the previous actions, it is necessary to develop a "mental scenario" without the assistance of "physical" configuration cues.

Training Criterion

An ever present problem in the study of learning and (especially) retention is determining the appropriate criterion at which to discontinue training. The research literature cited in the Introduction has indicated the strong influence of the "amount of training" on retention. The "amount of training" can be viewed in two ways; training time (or number of trials) and terminal proficiency level. In the former case, the actual proficiency level of the trainees can vary extensively. This can result in difficulties in the interpretation of retention scores. However, the latter (proficiency) criterion has the disadvantage that, although the trainees meet the same criterion, some perform many more trials than others. Although these two approaches each have theoretical advantages and disadvantages, the proficiency level criterion is more realistic in most operational settings. Therefore, that alternative was chosen for the present study.

The problem remains, however, as to "what" the proficiency level should be and how it is assessed (e.g., less than x errors, x number of perfect trials, etc.). The present study approached this question from a quality assurance point of view. Using the analogy of a quality assurance situation, the sample size in this experiment was 118 (possible errors during any one trial, see Appendix A). The acceptable quality level (AQL) of 1% was adopted as appropriate for a retention experiment. Using the Military Standard 105D multiple sampling plan, the acceptance and rejection values were as follows:

Trial	Accept If No. of Errors is Equal to or Less Than	Reject If No. of Errors is More Than
x	0	5
x+1	3	8
x+2	6	10
x+3	8	13
x+4	11	15
x+5	14	17
x+6	18	19

The first trial on which the trainee made less than five errors was designated as the first criterion trial (x). If the trainee made zero errors, he met criterion (was considered trained). Otherwise, he performed another trial. On this trial (x+1), if his cumulative performance (errors on trials x plus x+1) was three or less he met criterion. If his number of cumulative errors was eight or more, it was determined that he had gotten into the criterion trials by chance and he was taken out of the criterion trials and continued performing the task. If, on the other hand, his cumulative errors were between three and eight, he performed another trial, and so on.

The benefit of this strategy is twofold. First, it accounts for temporary fluctuations (positive and negative) in performance. Second, if a trainee reaches criterion trial x+6, he is assumed to be trained at his characteristic asymptotic level. That is, to reach trial x+6, the trainee had to perform six trials consecutively with either two or three errors on each trial.

Retention Evaluation Tests

An evaluation of the retention attributes of the three instructional strategies was conducted after an interval of 70 days ($\pm$10 days) for each subject. Of the original 60 subjects, 54 returned for the retention tests. The other six had left the area.

The procedure followed during the retention tests involved the trainee performing the task two successive times on the operational equipment. Prior to the two trials, a five minute orientation time was allowed for the subject to refamiliarize himself with the equipment. The trainees were not allowed to manipulate the equipment during this time. Feedback as to errors and the correct action was presented only for the step involving the error (the previous and next steps were not included in the feedback).

Retraining

After the two retention trials were performed, the trainees relearned the task to the same criterion as that used in original training. The procedure followed during retraining was identical to the procedure used during original training under the three respective training strategies (devices) with the exception that the initial instructions and demonstrations were not given. The retraining procedure involved a "proficiency confirmation trial" on the operational equipment, as in the original training. The specific reason for that trial in the retraining (and transfer) case was to collect more data on the device transfer of training problems (as opposed to the task transfer of training problems discussed in the next section).

Task Transfer of Training

After a short (5 to 10 minute) rest period, the trainees then participated in the transfer part of the experiment. The transfer task itself was described in a previous section. The procedure in this part of the study was identical to the original learning procedure with the exception of not including illustrated instructions. Rather, the trainee observed one demonstration of the new (transfer) task on the operational equipment and one on the training device. The trainee then practiced the transfer task on the training device until criterion was met and next performed the transfer task on the operational equipment.

Subjects

Sixty paid subjects (36 males and 24 females) participated in the study. The subjects ranged in age from 16 to 34 years. None of the subjects had had <u>extensive</u> previous experience in procedural tasks or training programs involving procedural tasks and they were representative of incoming trainees to such programs. For example, such groups as aircraft pilots have had extensive previous experience that could significantly influence their performance and were, therefore, excluded as participants.

The subject sample size was determined by estimating the standard deviation expected in the current study on the basis of the results obtained by Grimsley (1969). In that experiment, which utilized a 92 step procedure, a standard deviation of approximately six errors occurred in the retention scores. Using this estimate, and a desired detectability level of five errors, the value of λ was approximately 0.6. Referring to the Operating Characteristic Curve for a two tailed test with an acceptable α error of 0.05 and acceptable β error of 0.20, the resulting necessary sample was 20 subjects within each of the three experimental conditions.

Sheehan's short form of the Betts Questionnaire Upon Mental Imagery and the Gordon Test of Visual Imagery Control (see Richardson, 1969) were administered to the subjects prior to their performing the experiment.

Reproductions of these questionnaires are included in Appendix D. In addition to the imagery tests, four sections of the Wechsler Adult Intelligence Scale (picture completion, arithmetic, digit span, and digit symbol) were administered to the subjects.

The scores on both the imagery and the WAIS tests were filed without the experimenter knowing the results. This "blind procedure" reduces the possibility of demand characteristics in which the experimenter unknowingly biases the results.

Twenty subjects were randomly assigned to each of the three training strategies. Of the 60 subjects, 54 returned for the remainder of the study. The other six subjects had left the area. Of the 54 returning subjects, 20 were in the conventional strategy group, 18 were in the reproduction, and 16 were in the blind strategy group.

Experimental Variables

The variables involved in this study can be classified into five categories: (1) independent variable, (2) concomitant variable, (3) subject variables, (4) treatment variables, and (5) performance variables. Each of these categories is analyzed differently.

Independent Variable. The independent variable studied in this experiment was the training strategy. The three strategies which made up this factor were characterized by the manner of use of the three training devices described in the last section.

Concomitant Variable. It was anticipated that the vividness of imagery would interact with the training strategies. Vividness of imagery as assessed by the visual, auditory, kinesthetic, and tactile parts of the shortened Betts QMI, was treated as a concomitant variable and was partialed out of the analysis of the independent variable through covariance adjustment. The relationship of imagery and performance was also studied in a regression analysis.

Subject Variables. Five measures were used to characterize the subjects. The subject's self rating on the Gordon Test of Imagery Control was used to assess the subject's ability to manipulate imagery. The scores from four sections of the Weschler Adult Intelligence Scale (arithmetic, digit span forward, digit span backward, and digit symbol) were used to indicate the subject's symbol manipulation capability. In addition to these tests, the subject's age, sex, and year in school (if a student) were recorded.

Treatment Variables. In order to assess the influence of uncontrolled aspects of subject treatment, three measures were used. Due to scheduling problems, there was some variability in the retention interval for the subjects (70 days ± 10). The retention interval was recorded and its effect on retention, retraining, and transfer was analyzed. In that two experimenters were used to collect the data for each subject (the author and a graduate student in Human Factors), the experimenter that trained the subject was recorded. The experimenter effect was subsequently evaluated. Another treatment that varied among subjects was the time of day that they performed in the training and retention, retraining, and transfer sessions.

Performance Measures. The performance measures (dependent variables) used to evaluate the effectiveness of the training strategies can be divided into error measures, performance time measures, and device transfer measures. The first type of measure involves sequence and setting errors. The second pertains to the time required to perform the task. The last type of measure assesses the problems in learning a task on a training device and then transferring to the operational equipment. There were separate performance measures recorded for each phase of the study; training, retention, retraining, and task transfer. Table 1 presents a listing of the performance measures.

The primary measure of the training effectiveness of the devices was the number of trials necessary for the subject to meet the training criterion. In addition to the "trials to criterion" measure, the number of both sequencing errors and setting errors and the total number of errors made during the training trials were also recorded. With respect to the time required to perform the task, three measures were used: (1) time to perform first trial, (2) time to perform last (training) trial, and (3) total training time. The number of errors made on the "proficiency confirmation trial" was recorded to evaluate the device transfer effects.

The performance measures used for the retention phase of the study included the number of both sequencing and setting errors made on the first retention trial. In addition, the number of errors reduced from the first to the second retention trials and the percent of error reduction (errors on second divided by errors on first) were recorded.

The same performance measures were used for the retraining phase of the study as those used in the training phase. The only measures used in the training phase that were not used during retraining were the times to perform the first and last trials.

The measures used during the task transfer phase were the same as those used in retraining. During transfer, however, an additional record was made of the number of errors made on the first trial of the transfer training.

Table 1. Performance Measures

Performance Measures for Initial Training

- Number of trials needed to attain criterion performance.
- Total number of errors made across all training trials.
- Total number of sequence errors made across all training trials.
- Total number of setting errors made across all training trials.
- Total time required in performing all training trials.
- Time required to perform first training trial.
- Time required to perform last training trial.
- Number of errors made on the proficiency confirmation trial.

Performance Measures for Retention Evaluation

- Total number of errors made on the first retention trial.
- Number of sequence errors made on the first retention trial.
- Number of setting errors made on the first retention trial.
- Decrease in the number of errors from first to second trial.
- Percent decrease from first to second trial.

Performance Measures for Retraining

- Number of trials needed to attain criterion performance.
- Total number of errors made across all retraining trials.
- Total number of sequence errors made across all retraining trials.
- Total number of setting errors made across all retraining trials.
- Total time required in performing all retraining trials.
- Number of errors made on the proficiency confirmation trial.

Performance Measures for Transfer of Training

- Number of trials needed to attain criterion performance.
- Total number of errors made across all transfer trials.
- Total number of sequence errors made across all transfer trials.
- Total number of setting errors made across all transfer trials.
- Number of errors made on the first transfer trial.
- Total time required in performing all transfer trials.
- Number of errors made on the proficiency confirmation trial.

EXPERIMENTAL HYPOTHESES

Effect of Instructional Strategy

The effect of instructional strategy on initial training time was anticipated to be in favor of the conventional repetitive practice strategy both in terms of meeting the criterion and the shape of the learning curve. In analyzing the operational task, it is evident that the availability of calibrations and numerical values on the controls and displays are a salient cue to the trainee (recognition memory). The task of performing the procedure without these cues was a more difficult task (requiring more recall memory) and, therefore, it was expected that the time to initially learn the procedure would be longer for the experimental strategies. Using this rationale, it was anticipated that the order of merit in terms of rapid learning would be the conventional strategy, followed by the reproduction strategy, and in turn, followed by the imagery strategy.

However, retention of the ability to perform the procedure over time is where the utility of the experimental strategies was expected to be exhibited. Two aspects of the latter strategies lend themselves to better retention. The first aspect pertains to the fact that the reproduction strategy and particularly the imagery strategy were more difficult (e.g., requiring recall memory) than the actual operational task (e.g., requiring recognition memory). This increased difficulty in the experimental strategies could be interpreted as "over training" which would result in superior retention. The second aspect involves the efficiency of encoding and storing information in memory. If mental imagery representations are more effective than logical or symbolic representations, then the experimental strategies should have resulted in superior retention with the imagery strategy being the best.

A situation that is often encountered in the work environment is where there are minor changes to the sequence of actions and/or the desired control settings in a procedure. An instructional strategy that can increase an operator's ability to transfer the original training to the new task is, therefore, desirable. One hypothesis relevant to this study was that a "mental imagery organization" of information is more adaptable to changes in the task (i.e., less susceptible to interference) than is a "logical, symbolic" organization. That is, accessing an imagery representation would be more efficient than accessing a logical representation when transferring from one task to another. Under this hypothesis, the experimental strategies would be superior to the conventional strategy in learning the new task.

Interaction of Instructional Strategy and Perceptual Style

Although the main effect of perceptual style in training, retention, and transfer was of interest in the present study, its interaction with instructional strategy was of major importance. The basic hypotheses concerning this interaction predicted that the trainees with more vivid imagery would perform better under the experimental strategies relative to the trainees with low imagery vividness. Similarly, it was anticipated that low imagers would perform better under the conventional strategy relative to the high imager. This relationship was anticipated to be consistent across all training conditions (initial training, retention, and transfer of training).

RESULTS AND DISCUSSION

A number of separate analyses were performed to test the hypotheses discussed in the previous section. The error and performance time data were submitted to an analysis of variance and covariance to evaluate the relative effectiveness of the three training strategies. In addition, a regression analysis was performed to investigate the relationship of mental imagery and the performance measures. The analysis of variance (performance time data) and the analysis of covariance (error data, Betts imagery test score covaried) were one way analyses involving three factor levels of training strategy; conventional, reproduction, and blind.

The tabular results of the analyses present the means and standard deviations of the measures (and their transforms when necessary) within each of the three factor levels. The tables include the F ratio, number of degrees of freedom, significance level, and individual means comparisons using the Neuman-Keuls test. Although the alpha errors for both $p < .10$ and $p < .05$ are presented for the reader, the criterion for rejecting the null hypotheses was $p < .05$ for the present study. Therefore, only those measures that were reliable beyond the .05 level will be discussed as being statistically significant.

Preliminary Analyses

Preliminary tests of the normality and homogeneity assumptions of analysis of variance and regression analysis were conducted. The χ^2 test was used to test the normality assumption and the F_{max} test was used to test for homogeneity of variance (proportionality of means and variances). The raw data were transformed for the measures that violated one or both of these assumptions ($p < .10$). The range statistic was used to choose a transformation. On the basis of this test, the square root transformation was chosen. The transformation, $\sqrt{x} + \sqrt{x+1}$ was used for measures with values less than ten (Winer, 1971).

Analyses of Task Performance Times

The means and standard deviations of the performance time measures (and their transforms) are presented in Table 2. An analysis of variance was performed on the data, the results of which are presented in Table 3.

A strong effect that was observed during original training was the difference among the training times for the three strategies. This effect was indicated for total training time, time to perform the first trial, and time to perform the last trial. During the first trial, the task practiced under the conventional strategy was performed the fastest, followed by the reproduction, and then the blind strategy.

This is consistent with the assumed information processing activities (and resulting time) that are required under each of the strategies. The trainee was provided with cues from the calibrations and numerical values on the controls and displays in the conventional strategy that he did not have available in the experimental (reproduction and blind) strategies. With respect to feedback as a result of previous actions and the subsequent cueing of the next action, the conventional and the reproduction strategies provided the trainee with a "hard copy" representation of the effect of his previous actions that was not provided

Table 2

MEANS AND STANDARD DEVIATIONS OF PERFORMANCE TIME MEASURES AND THEIR TRANSFORMS (IN MINUTES)

	STRATEGY					
	CONVENTIONAL		REPRODUCTION		BLIND	
MEASURES	MEAN	SD	MEAN	SD	MEAN	SD
INITIAL TRAINING						
TIME ON FIRST TRIAL	17.14	4.59	19.37	5.40	22.25	7.14
TIME ON LAST TRIAL	6.86	1.36	6.90	2.20	8.28	1.74
TOTAL TRAINING TIME	71.86	26.64	84.80	37.48	106.71	49.32
(TRANSFORMED)	8.35	1.51	9.02	1.91	10.12	2.12
RETRAINING						
TOTAL TRAINING TIME	27.69	12.73	29.37	7.67	31.54	10.87
TRANSFER						
TOTAL TRAINING TIME	29.39	10.01	31.08	18.98	42.61	22.64
(TRANSFORMED)	5.35	0.91	5.37	1.55	6.33	1.67

Table 3

SIGNIFICANCE TABLE FOR PERFORMANCE TIME MEASURES AND THEIR TRANSFORMS

MEASURES	F	dF	$p < .05$	$.05 < p < .10$	MEANS* COMPARISON
TRAINING					
TIME ON FIRST TRIAL	3.76	2,56	0.030		C;B
TIME ON LAST TRIAL	3.57	2,56	0.036		C,R;B
TOTAL TRAINEE TIME (TRANSFORMED)	4.15	2,56	0.021		C,R;B
RETRAINING					
TOTAL TRAINING TIME	<1	2,50			
TRANSFER					
TOTAL TRAINING TIME (TRANSFORMED)	2.74	2,50		0.074	

* C,R;B INDICATES THAT $\bar{X}_C$ AND $\bar{X}_R$ ARE STATISTICALLY DIFFERENT FROM $\bar{X}_B$ BUT NOT DIFFERENT FROM EACH OTHER AS DETERMINED BY NEUMAN KUELS TESTS (C = CONVENTIONAL R = REPRODUCTION, AND B = BLIND).

in the blind strategy. The processing (memory recall) time for the reproduction strategy should be longer than for the conventional strategy in that the latter provides initial cueing; however, it should be faster than for the blind strategy in that results of previous actions are provided and do not need to be mentally reconstructed as in the blind strategy. Finally, the time necessary to perform the task under the blind strategy should be the longest in that memory (and the resultant processing time) must be used to both cue the trainee in terms of display and control settings, as well as to reconstruct the results of previous actions.

All three strategies were significantly different from each other for the time to perform the first trial. However, only the blind strategy was different from the other two in the total training time and the time to perform the last trial. This result could indicate that having calibrations and numerical values visible is less important (or at least takes less time) than the reconstruction of the results of previous actions. In that there is also a possible differential learning effect relative to these measures, it is also feasible that the numerical settings are so "overlearned" by the time that the sequence is learned (last trial) that it takes less time (per recall) at the end of training. That is, during the first trial, recall of the settings takes a significant amount of time and, therefore, contributes to the difference among all three conditions. However, during the last trial, if the recall of settings is rapid (due to overlearning), then the reconstruction of past actions is the prime contributor to the performance time. In this case, only the blind strategy should differ from the conventional and reproduction strategies, with the latter two not being significantly different.

An important aspect of training time in evaluating a training strategy is the cost effectiveness of the strategy. For example, in the present case, the experimental strategies (paper and pencil) would be cheaper to implement than having the trainees practice on the operational equipment or on a high fidelity mock-up. However, if the time required to train the individual is longer, the cost effectiveness of the strategy is proportionately reduced.

The results of this study indicate that the total time to learn on the blind strategy is approximately 1.5 times as long as that required to learn on the conventional strategy. Therefore, the total operation and maintenance cost of the blind strategy would have to be more than 35 percent less costly than the conventional strategy to make it cost effective (all other things being equal). The time required to learn on the reproduction strategy is closer to that of the conventional strategy. In this case, the costs for the reproduction approach would only have to be 15 percent less expensive than the conventional to make it cost effective.

Analyses of Error Measures

The means and standard deviations of the error performance measures (and their transforms) are given in Table 4 for each of the training strategies. In that it was anticipated that vividness of imagery would interact with the training strategies, with respect to error scores, an analysis of covariance was performed on the data. Table 5 illustrates the results of that analysis.

The usual measure of the effectiveness of a training approach is the number of trials required to learn the task rather than the amount of

Table 4

MEANS AND STANDARD DEVIATIONS OF
ERROR MEASURES AND THEIR TRANSFORMS

MEASURE	CONVENTIONAL		REPRODUCTION		BLIND	
	MEAN	SD	MEAN	SD	MEAN	SD
TRAINING						
TRIALS TO CRITERION	6.55	2.55	7.61	2.32	7.75	1.64
TOTAL ERRORS	49.85	25.70	62.17	30.50	73.44	30.13
SEQUENCE ERRORS	41.70	20.06	52.17	26.22	55.94	25.12
SETTING ERRORS	8.00	6.82	10.11	6.84	17.81	10.96
RETENTION						
TOTAL ERRORS	42.05	6.19	37.50	4.59	39.81	6.80
SEQUENCE ERRORS	28.65	7.21	25.00	4.74	26.13	6.31
SETTING ERRORS	12.85	3.91	12.50	2.70	13.69	2.27
(TRANSFORMED)	3.54	0.61	3.51	0.40	3.69	0.31
DECREASE IN ERRORS	26.15	6.63	22.39	4.08	22.94	6.07
PERCENT DECREASE	37.30	10.02	39.94	10.71	41.87	12.81
RETRAINING						
TRIALS TO CRITERION	3.75	1.55	3.88	0.96	3.81	0.91
TOTAL ERRORS	14.85	10.81	16.27	8.35	18.88	12.57
SEQUENCE ERRORS	13.15	10.16	13.88	7.71	14.69	8.11
SETTING ERRORS	1.70	1.66	2.44	1.79	4.19	5.65
(TRANSFORMED)	2.61	1.30	3.16	1.27	3.72	2.23
TRANSFER						
TRIALS TO CRITERION	4.25	1.29	4.33	1.81	5.31	2.09
TOTAL ERRORS	21.85	12.24	23.72	22.75	37.69	27.06
(TRANSFORMED)	4.49	1.32	4.38	2.19	5.79	2.10
SEQUENCE ERRORS	17.30	9.20	19.78	19.23	27.00	17.30
(TRANSFORMED)	4.02	1.08	4.03	1.93	4.96	1.61
SETTING ERRORS	4.80	3.76	4.11	4.21	10.63	10.60
(TRANSFORMED)	4.69	4.03	4.42	4.81	6.48	5.94
ERRORS ON FIRST TRIAL	11.25	5.55	9.72	6.57	15.38	6.67

Table 5

SIGNIFICANCE TABLES FOR ERROR MEASURES AND THEIR TRANSFORMS

MEASURES	F	dF	p<.05	.05<p<.10	MEANS[1] COMPARISON
TRAINING					
TRIALS TO CRITERION	1.15	2, 56			
TOTAL ERRORS	1.68	2, 56			
SEQUENCE ERRORS	<1	2, 56			
SETTING ERRORS	4.87	2, 56	.011		C,R;B
RETENTION					
TOTAL ERRORS	3.44	2, 50	.040		C;R
SEQUENCE ERRORS	3.32	2, 50	.044		C;R
SETTING ERRORS (TRANSFORMED)	<1	2, 50			
DECREASE IN ERRORS	2.79	2, 50		.071	
PERCENTAGE DECREASE	<1	2, 50			
RETRAINING					
TRIALS TO CRITERION	<1	2, 50			
TOTAL ERRORS	<1	2, 50			
SEQUENCE ERRORS	<1	2, 50			
SETTING ERRORS (TRANSFORMED)	1.29	2, 50			
TRANSFER					
TRIALS TO CRITERION	1.30	2, 50			
TOTAL ERRORS (TRANSFORMED)	2.10	2, 50			
SEQUENCE ERRORS (TRANSFORMED)	1.29	2, 50			
SETTING ERRORS (TRANSFORMED)	3.86	2, 50	.028		C,R;B
ERRORS ON FIRST TRIAL	2.97	2, 50		.060	

[1] INDIVIDUAL MEANS COMPARISON USING NEUMANN - KEULS TEST ($p<.05$). C,R;B INDICATES THAT CONVENTIONAL AND REPRODUCTION DID NOT DIFFER, HOWEVER, THE BLIND CONDITION DIFFERED FROM BOTH. C;R INDICATES THAT CONVENTIONAL AND REPRODUCTION DID DIFFER.

time necessary. It was originally anticipated that the conventional strategy would be superior (fewer trials to criterion) in this respect, followed by the reproduction and then the blind strategy. Although the rank order of the means for these conditions are consistent with this anticipation, the differences among the strategies were not statistically significant ($p > .10$). The same lack of significance occurred for both the total number of errors and the number of sequence errors. This result is consistent with much of the literature on training devices (Cox, et al. 1965; Grimsley, 1969a, 1969b; Mirabella, 1974; Sitterly, 1974). That is, the results of the present study support the idea that the complexity (fidelity) of a training device does not necessarily impact upon the number of trials an individual must perform to learn a task.

The one measure that did illustrate a difference among the strategies was the number of setting errors. The conventional and the reproduction strategies were reliably different from the blind strategy in this respect. This was the case during both initial training and task transfer trials. The difference between the conventional and the blind strategy is not surprising in that the conventional strategy provides cues to the trainee as to the range of values appropriate for a setting (e.g., 0 to 100 vs 0 to 10) and the fineness of the graduation (1s, 10s, etc.). This additional information should lead to fewer setting errors. The fact that the reproduction strategy grouped with the conventional and was significantly different from the blind strategy is somewhat surprising. If the aforementioned cueing accounts for the difference between the conventional and blind strategies, then the reproduction strategy should group with the blind strategy.

One possible explanation of the obtained results is that setting errors can be reduced by eliminating the possibilities as they are used. That is, in both the conventional and reproduction cases, the trainee can view the "hard copy" of previous settings and eliminate those from his possible future settings. This "hard copy" is not available in the blind case; but rather, the trainee must utilize memory to eliminate the settings he has previously used.

Because the blind strategy required the use of memory, it was anticipated to be superior for task retention. However, in retention, the reproduction strategy was significantly superior to the conventional strategy on the basis of the total number of errors, with the blind strategy being between the other two (not significantly different from either). This effect was primarily due to sequence errors rather than setting errors.

Therefore, although setting errors is a good discriminator among the strategies during training, it is the sequence errors that discriminate among them for retention purposes. This conclusion is also supported (for the present study) by the performance time result previously discussed. The conclusion was that time differences on the last trial might be explained by the occurrence of over-learning with regard to settings by the time the entire sequence was learned. If this is the case, it is reasonable that the number of sequence errors rather than setting errors be used as a discriminator during retention trials.

There were no specific hypotheses related to the retraining. The retraining served to establish a baseline level for the task transfer portion of the study as a function of training strategy. There were no significant differences among the three strategies within either the error or the performance time measures. However, as with the training and transfer data, these data indicate that training device fidelity does not have to be high for refresher training. Particularly, once the individual has learned the task and performed it on the operational equipment, the training device does not have to be dynamic to relearn a task. This is consistent with the results found by Sitterly and Berge (1972) for emergency procedure refresher training.

The most sensitive measure of task transfer effects in this study was the number of errors made on the first transfer trial. Although the hypothesis that there is no difference among conditions cannot be rejected, the α error obtained was 0.06. As with the training trials, the number of setting errors was statistically significant for the first transfer trial. The blind strategy, again, was different from the other two.

Figure 5 illustrates the learning curves obtained during initial training for each of the three training strategies. Figures 6, 7, and 8 present Vincent learning curves for the three strategies within initial training, retraining, and task transfer training, respectively. Vincent curves present "standardized" scales for both the number of errors and the number of trials. The number of errors on the first trial is designated as the 100 percent point; similarly, the number of errors on the last trial is designated as the 0 percent point. The intermediate error scores are proportioned. The trials are similarly scaled with the first trial being 0 percent and the last trial being the 100 percent point. This method of presenting learning curves provides a comparison of the shape of the learning curves, independent of the difficulty level of each

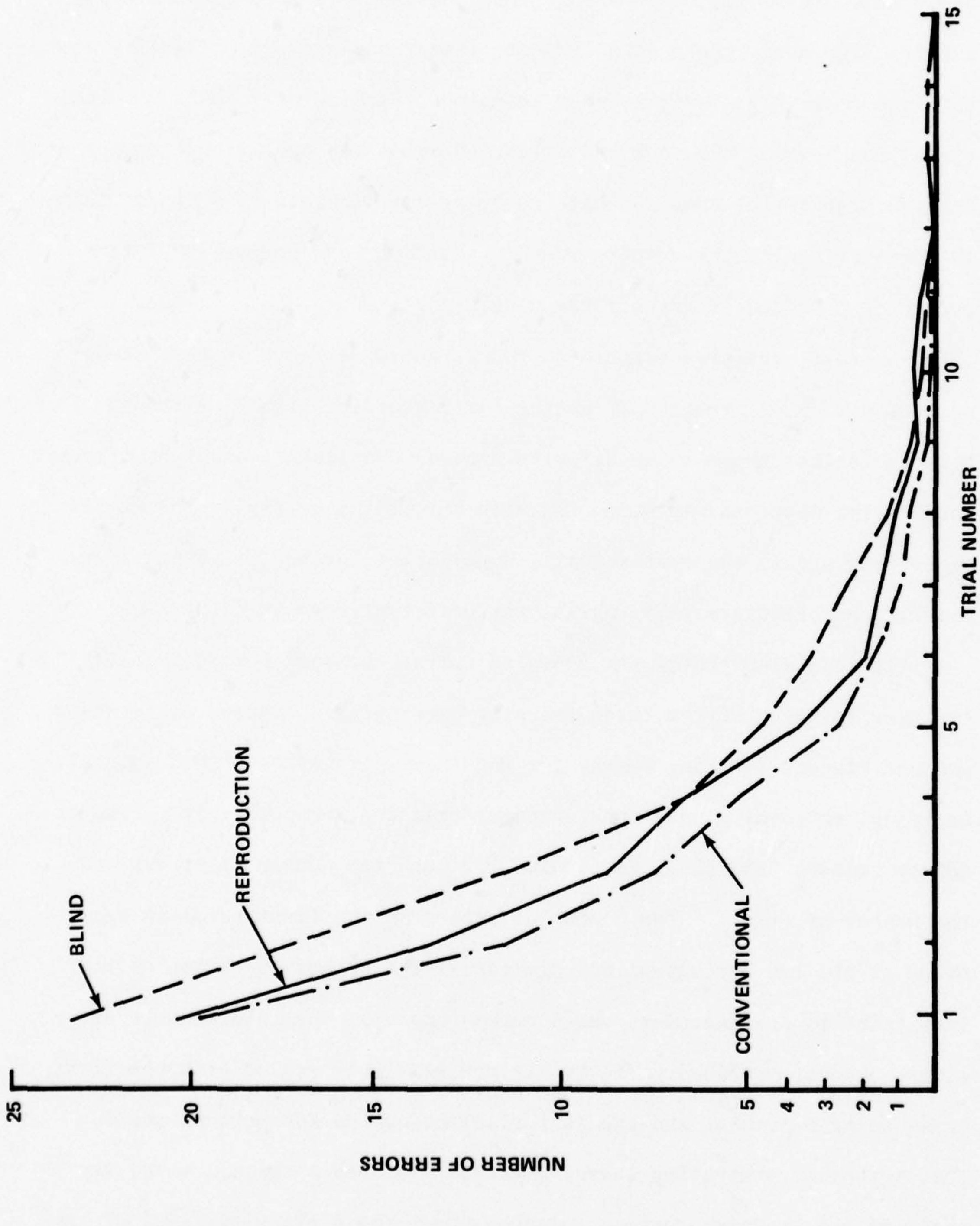
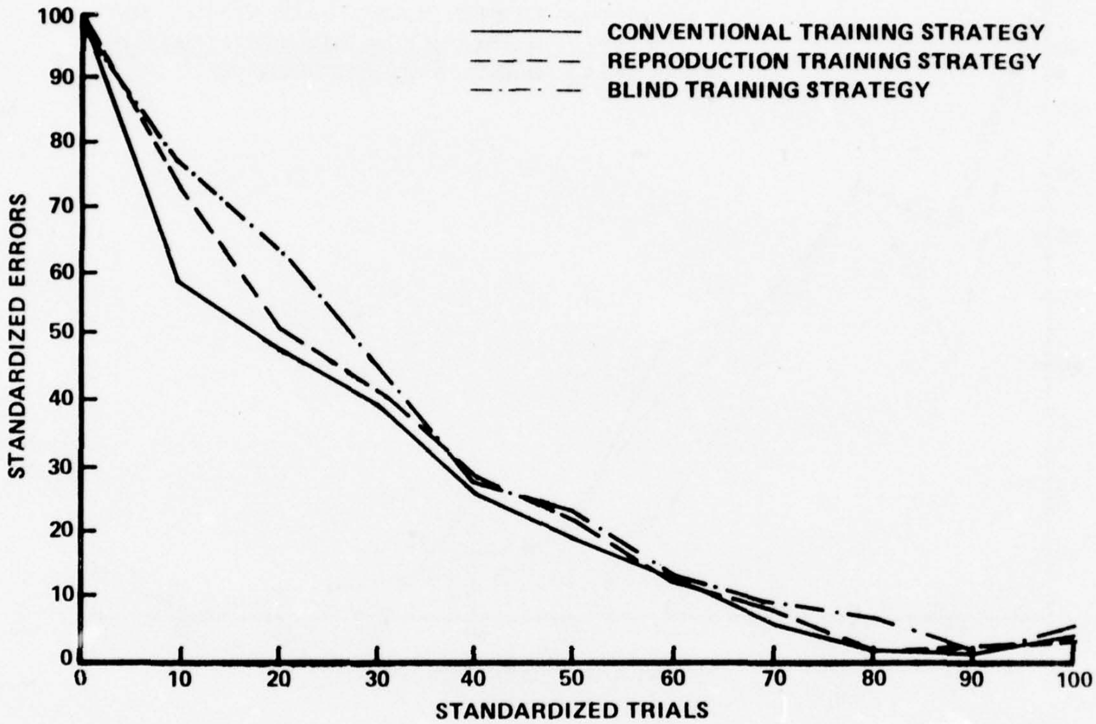
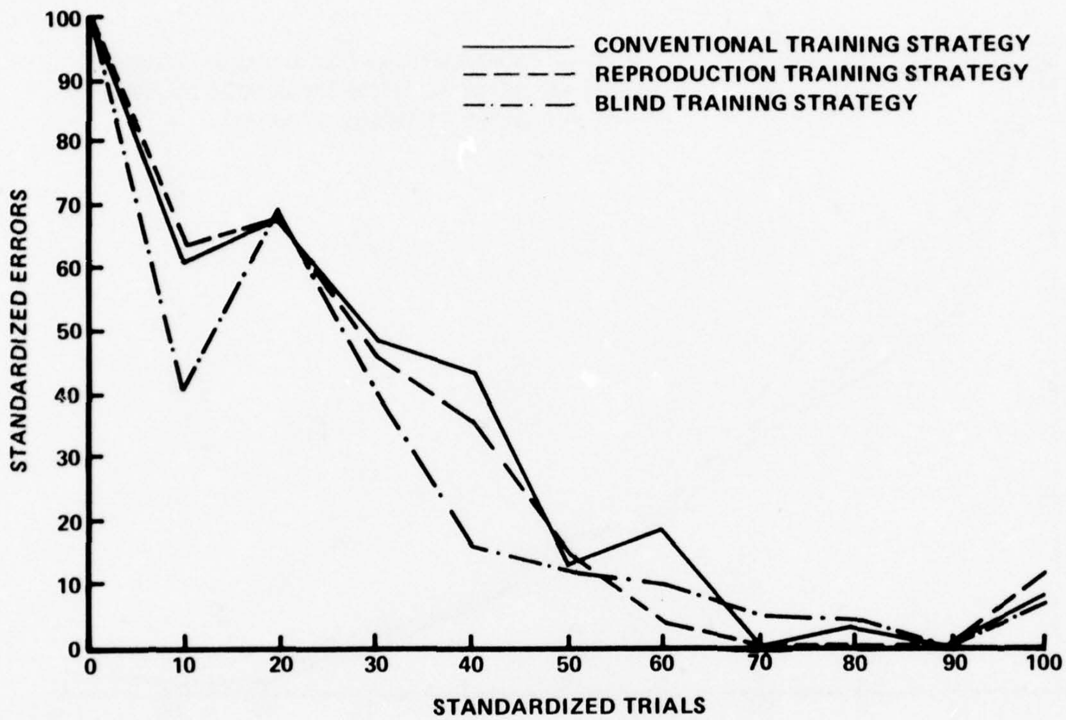


Figure 5 LEARNING CURVES FOR THE THREE TRAINING STRATEGIES



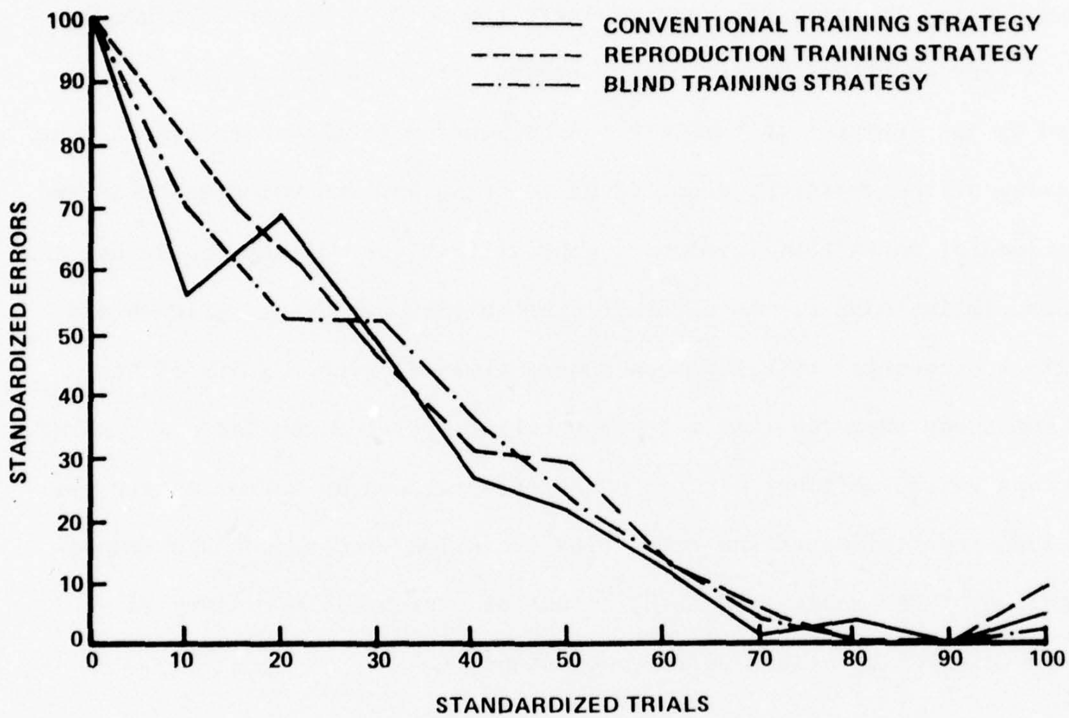
CONVENTIONAL											
$\overline{X}$	100	59.4	48.45	39.33	25.47	19.75	14.30	5.75	2.64	.90	3.15
n	20	10	11	15	15	8	15	12	14	10	20
SD	–	17.48	11.56	16.43	12.66	12.79	9.21	7.24	3.86	1.91	3.67
REPRODUCTION											
$\overline{X}$	100	73.23	51.00	41.15	28.18	21.93	12.57	6.67	2.47	2.64	2.75
n	20	11	12	17	14	14	14	12	17	11	20
SD	–	12.18	16.41	11.81	8.04	13.78	7.05	8.80	5.91	4.88	3.40
BLIND											
$\overline{X}$	93.75	76.46	64.36	45.67	27.97	23.00	13.56	6.88	6.42	2.14	4.75
n	20	14	11	18	16	8	16	17	12	14	20
SD	–	13.96	18.17	17.71	10.10	8.11	8.40	7.20	5.78	2.66	4.06

Figure 6 VINCENT LEARNING CURVES FOR INITIAL TRAINING



CONVENTIONAL											
$\overline{X}$	100	62	67	48.3	43.7	125	18.3	0	3.9	0	7.5
r	20	1	3	14	3	11	3	8	8	2	20
SD	–	–	14.7	18.4	11.0	14.6	6.1	0	6.2	0	10.7
REPRODUCTION											
$\overline{X}$	100	63	67	45.5	35.3	14.3	4.3	0	1.1	0	15.8
r	19	1	6	11	7	9	7	4	13	1	19
SD	–	–	25.4	20.1	21.2	16.2	23.6	0	2.6	0	26.7
BLIND											
$\overline{X}$	100	41	68	41.9	16.5	12.3	10	5	4.1	0	6.9
r	17	1	2	15	2	12	2	5	9	1	17
SD	–	–	1.4	16.9	2.1	13.4	2.8	8.7	8.8	0	9.6

Figure 7 VINCENT LEARNING CURVES FOR RETRAINING



CONVENTIONAL

X̄	98.85	56	68.1	48.4	26.4	21.4	11.3	1.3	3.8	0	4.5
n	20	1	7	14	7	8	7	8	12	2	20
SD	3.96	–	18.3	23.5	10.1	22.5	8.7	2.4	8.5	–	2.4

REPRODUCTION

X̄	100	80	63.4	46.9	30.5	25.9	13.7	5.1	.6	0	9.6
n	19	1	8	16	2	9	3	14	10	1	19
SD	–	–	15.6	26.5	2.1	18.4	15.2	17.4	1.9	–	10.8

BLIND

X̄	100	69.8	51.8	50.3	35	23.5	13.7	4.5	.6	0	2.4
n	16	4	4	15	5	12	5	6	13	4	16
SD	–	12.4	25.8	18.5	12.5	13.7	9.7	3.8	2.2	–	6.5

Figure 8 VINCENT LEARNING OF TRANSFER OF TRAINING

condition (in terms of initial errors and trials to criterion). Some of the irregularities in the curves are due to a limited number of observations falling in the range (particularly the 5 to 15 percent category).

A very important aspect of the present study was the context provided to the subjects in the task. As discussed in the introduction, the majority of the research conducted on training and retention has utilized experimental tasks that involve no context that the subjects could use in an associative manner. As a result, the ability of humans to learn and retain a sequential task has been underestimated. The results of the present study revealed that a representative operator can learn a task of 87 steps and 31 settings with no checklist provided in approximately six to seven repetitions of the task. The inclusion of a reasonable (representative of the real world task) amount of context is necessary in future research to assure valid conclusions.

Analyses of Device Transfer Errors

The means and standard deviations of the device transfer errors are presented in Table 6. The analysis of covariance results from these data are presented in Table 7.

Possibly, one of the most important results of the present study is the ease with which the trainees transferred from the experimental (paper and pencil) training devices to the operational equipment (device transfer). In both training and task transfer portions of the experiment, no differences were significant in terms of transfer from the experimental devices to the operational equipment ($p > .25$). In the retraining portion of the study, the differences were not significant (although they

Table 6

MEANS AND STANDARD DEVIATIONS OF DEVICE TRANSFER ERRORS AND THEIR TRANSFORMS

MEASURES	STRATEGY					
	CONVENTIONAL		REPRODUCTION		BLIND	
	MEAN	SD	MEAN	SD	MEAN	SD
TRAINING DEVICE TRANSFER ERRORS	1.15	0.58	1.17	0.62	1.56	1.20
(TRANSFORMED)	2.46	0.59	2.49	0.53	2.61	1.08
RETRAINING DEVICE TRANSFER ERRORS	0.60	0.68	1.06	0.73	1.06	0.77
TRANSFER DEVICE TRANSFER ERRORS	0.65	0.81	1.17	0.99	1.13	2.41
(TRANSFORMED)	2.61	1.30	3.16	1.27	3.72	2.23

Table 7

SIGNIFICANCE TABLE FOR DEVICE TRANSFER ERRORS AND THEIR TRANSFORMS

MEASURES	F	dF	p
TRAINING DEVICE TRANSFER ERRORS (TRANSFORMED)	>1	2, 56	$>.25$
RETRAINING DEVICE TRANSFER ERRORS	2.68	2, 50	.079
TRANSFER DEVICE TRANSFER ERRORS (TRANSFORMED)	1.11	2, 50	$>.25$

were not above the .25 level). Only twice in the 108 device transfer trials (40 during training, 34 during retraining, and 34 during transfer) did a subject make more than two more errors on the operational equipment than on the last training trial.

Regression Analyses of Imagery

A variable of primary interest in the present study was mental imagery. Table 8 presents the correlation of the imagery scores and the various performance measures. In addition, Table 8 also presents the regression coefficients and the t statistics for the coefficients. Table 9 illustrates the relationship of the regression coefficients within each of the three training strategies.

Originally, it was anticipated that there would be little effect of imagery on the conventional strategy, and that in the blind strategy, the more vivid imager would perform better than the less vivid imager. However, the data supported just the opposite which led to a major finding of the study.

The vividness of imagery had a much more predominant effect within the conventional training strategy relative to the two experimental conditions. Referring to Table 9, 15 of the 26 relationships between imagery and the performance measures were statistically significant when using the conventional strategy. For the reproduction strategy, only one relationship was significant, while there were eight for the blind strategy. These results indicate that the conventional strategy is sufficient (or possibly superior) for the less vivid imager but that it is handicapping

Table 8

REGRESSION ANALYSIS OF IMAGERY AND THE PERFORMANCE MEASURES

MEASURE	r	β	$p \leq .05$	$.05 < p < .10$
INITIAL TRAINING				
TRIALS TO CRITERION	.19	.032		X
TOTAL ERRORS	.36	.790	.001	
SEQUENCE ERRORS	.34	.605	.001	
SETTING ERRORS	.31	.191	.05	
TRAINING TIME FIRST TRIAL	.18	.074		X
TRAINING TIME LAST TRIAL	.33	.045	.001	
TOTAL TRAINING TIME	.39	1.133	.001	
DEVICE TRANSFER ERRORS	-.03	-.002		
RETENTION EVALUATION				
TOTAL ERRORS	.45	.250	.001	
SEQUENCE ERRORS	.41	.195	.001	
SETTING ERRORS	.18	.044		X
DECREASE IN ERRORS	.15	.066		
PERCENT DECREASE	.27	.002	.05	
RETRAINING				
TRIALS TO CRITERION	.26	.023	.05	
TOTAL ERRORS	.44	.033	.001	
SEQUENCE ERRORS	.42	.280	.001	
SETTING ERRORS	.19	.048		X
TOTAL TRAINING TIME	.38	.306	.001	
DEVICE TRANSFER ERRORS	-.08	-.004		
TRANSFER OF TRAINING				
TRIALS TO CRITERION	.19	.025		X
TOTAL ERRORS	.23	.373	.05	
SEQUENCE ERRORS	.24	.279	.05	
SETTING ERRORS	.18	.092		X
ERRORS ON FIRST TRIAL	.18	.086		X
TOTAL TRAINING TIME	.19	.249		X
DEVICE TRANSFER ERRORS	.01	.001		

Table 9

REGRESSION ANALYSIS OF IMAGERY BY TRAINING STRATEGY

MEASURE	STRATEGY					
	CONVENTIONAL		REPRODUCTION		BLIND	
	r	β	r	β	r	β
INITIAL TRAINING						
TRIALS TO CRITERION	.38	.045**	-.09	-.016	.47	.103**
TOTAL ERRORS	.43	.802**	.25	.538	.45	1.277**
SEQUENCE ERRORS	.39	.563**	.20	.374	.49	1.166**
SETTING ERRORS	.47	.230**	.37	.179	.12	.129
TRAINING TIME FIRST TRIAL	.49	.943**	.19	.224	.53	1.984**
TRAINING TIME LAST TRIAL	.24	.023	.56	.087**	.05	.009
TOTAL TRAINING TIME	.45	.861**	.22	.572	.62	2.870**
DEVICE TRANSFER ERRORS	-.26	-.011	-.17	-.008	.26	.030
RETENTION EVALUATION						
TOTAL ERRORS	.74	.496**	.12	.040	.22	.144
SEQUENCE ERRORS	.57	.293**	.27	.090	.33	.193
SETTING ERRORS	.62	.174**	-.27	-.051	-.23	-.049
DECREASE IN ERRORS	.56	.265**	-.29	-.083	-.11	-.065
PERCENT DECREASE	.23	.002	.35	.003	.24	.003
RETRAINING						
TRIALS TO CRITERION	.48	.052**	-.18	-.012	.41	.035
TOTAL ERRORS	.54	.424**	.22	.129	.46	.540**
SEQUENCE ERRORS	.55	.396**	.17	.089	.55	.420**
SETTING ERRORS	.23	.027	.29	.036	.23	.120
TOTAL TRAINING TIME	.51	.464**	.18	.095	.39	.393
DEVICE TRANSFER ERRORS	.05	.003	-.39	-.020	.14	.010
TRANSFER OF TRAINING						
TRIALS TO CRITERION	-.09	-.009	.30	.038	.39	.076
TOTAL ERRORS	-.02	-.017	.29	.461	.41	1.047
SEQUENCE ERRORS	.01	.009	.30	.398	.39	.625
SETTING ERRORS	.02	.004	.09	.027	.42	.418**
ERRORS ON FIRST TRIAL	-.08	-.033	.28	.127	.42	.262**
TOTAL TRAINING TIME	-.22	-.158	.33	.443	.35	.740
DEVICE TRANSFER ERRORS	.42	.024**	-.30	-.020	-.05	-.011

**INDICATES A SIGNIFICANT β VALUE AT THE $p < .05$ LEVEL.

to the more vivid imager. Performance of low imagers was comparable to the performance of high imagers when the reproduction strategy was used. Furthermore, the mean performance of the reproduction strategy group was superior to the mean for the conventional strategy group. The resulting interaction, however, resulted in the relative performance being in the favor of the conventional strategy for the low imagers, but in the opposite direction for the high imagers. This also supports the contention that performance can be enhanced by matching the training strategy with the trainee's cognitive style.

Analysis of Subject Sex Effects

Subsequent to the initial analyses of the independent variable, a three-way analysis of covariance (imagery score covaried) was performed on the error scores and an analysis of variance was performed on the time scores. The factors included the sex of the subject (two levels), the experimenter (two levels), and training strategy (three levels). Table 10 illustrates the performance variables that were significantly different beyond the 0.10 and 0.05 levels. It should be noted that this is a post hoc analysis in that it is a second analysis on the same data that were used in the final (one-way) analysis of the independent variable, training strategy. Therefore, the reader may choose to be cautious in evaluating the "true" α level.

The analysis of sex differences reveals that females tend to be able to transfer from one task to another better than males. There were no differences between the sexes on the retention and retraining phases of

Table 10

SUMMARY OF SIGNIFICANT SEX DIFFERENCES

MEASURES	MALES	FEMALES	p
INITIAL			
TRIALS TO CRITERION	7.85	6.75	.071
TOTAL ERRORS	63.79	58.23	.093
SETTING ERRORS	13.38	8.35	.007
TOTAL TRAINING TIME	93.58	78.27	.036
TRANSFER OF TRAINING			
TRIALS TO CRITERION	5.13	4.15	.030
TOTAL ERRORS	32.93	20.11	.008
SEQUENCE ERRORS	26.03	16.76	.014
SETTING ERRORS	8.23	4.46	.011
ERRORS ON FIRST TRIAL	13.30	10.57	.026
TOTAL TRAINING TIME	38.38	27.81	.021
DEVICE TRANSFER ERRORS	1.083	1.007	.005

the study and the only difference observed during training was the total training time. There also were no interactions between sex and training device.

Analysis of Experimenter Effects

Another analysis that was conducted (also post hoc) evaluated the effect of experimenter in a three-way analysis of variance and covariance (two levels of experimenter, two levels of sex, and three levels of training strategy, Betts imager score covaried). Table 11 presents the results of this analysis.

The effect of experimenter on the number of trials to criterion illustrates the methodological problems that can plague this type of research. The experimental procedure was felt to be rigorous with respect to controlling the amount of information that the subject received during the sessions. However, such things as the enthusiasm of the experimenter can alter the motivation of the subject and subsequently alter his performance. In the present experiment, the effect of experimenter differences on the conclusions of study should be minimal. First, the subjects were pseudo-randomly (depending upon scheduling) assigned to be run by one or the other experimenter and this was counterbalanced across training strategies. Second, the correlation of the trials to criterion and the retention scores was not significant ($r = .13$), and retention was the primary area of interest in the study.

The research literature has discussed the relationship of post training proficiency level and retention (Naylor and Briggs, 1961;

Table 11

SUMMARY OF SIGNIFICANT EXPERIMENTER EFFECTS

MEASURES	EXPERIMENTER 1	EXPERIMENTER 2	p
INITIAL TRAINING			
TRIALS TO CRITERION	7.81	6.75	.033
SEQUENCE ERRORS	53.08	46.97	.065

Mengelkock, et al., 1961; Gardin and Sitterly, 1972). These studies have quantified post training proficiency on the basis of the number of training trials (e.g., 5 trials vs. 10 trials, Mengelkock, et al., 1961) rather than on the final performance level (e.g., number of errors). The correlation of the number of errors on the last training trial and the retention scores was not significant in the present study ($r = .09$). The interesting aspect of the results of the present study is that, if the student is trained to a relatively low error level, rapidly diminishing returns are gained from continued training, in that final error rate is not highly correlated with retention.

Although the literature also illustrates that the duration of the retention interval has an effect on retention (Naylor, et al., 1952; Neumann and Ammon, 1957) the regression coefficient of retention interval on retention scores was not significant ($r = .09$, $p > .25$).

SUMMARY

The study of mental imagery is an elusive area. The many studies cited in the Introduction pertain to mental (usually visual) imagery as a hypothetical construct. The reliability and predictive validity of imagery has been found to be reasonable; however, the content validity of imagery test has not been well developed. That is, whether imagery is really Hull's "s and r" or Tolman's cognitive maps or something else has not been established. The definition of imagery used for this study was taken from Funk and Wagnall's dictionary: "mental images collectively as created by imagination or memory." They further define image as "a mental representation of something not perceived at the moment through the senses, including the accompanying emotion." The training strategies evaluated during this study were designed to require varying degrees of imagery utilization through reductions in the stimuli that provide cueing and feedback. The standard for comparing the effectivenss of these strategies was conventional "repetition" of the task on the operational equipment.

The experimental strategies were found to have advantages for retention apparently without accompanying problems during training. The experimental strategies which used pencil and paper (35% scaled photograph) also did not lead to device transfer problems. These results, along with the cost benefits of using the simpler types of devices make the use of such training methods desirable.

Although the original idea was to develop a training strategy that increased retention due to the use of imagery, the results indicate that the conventional strategy actually hinders the high imagers. That is, high imagers do less well on the operational equipment than they do on both types of experimental strategy. The results of this study indicate that: (1) vividness of imagery <u>does</u> interact with training strategy, (2) training devices <u>do not</u> need to be high fidelity for procedural tasks, and (3) the use of an experimental strategy that requires the trainee to provide his own cueing and feedback from memory <u>is effective</u> in increasing the retention of procedure-following skills, particularly for low imagers.

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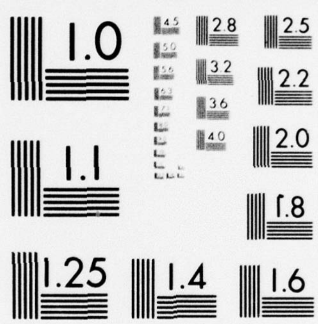

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APPENDIX A

SEQUENCE OF STEPS IN ORIGINAL LEARNING TASK

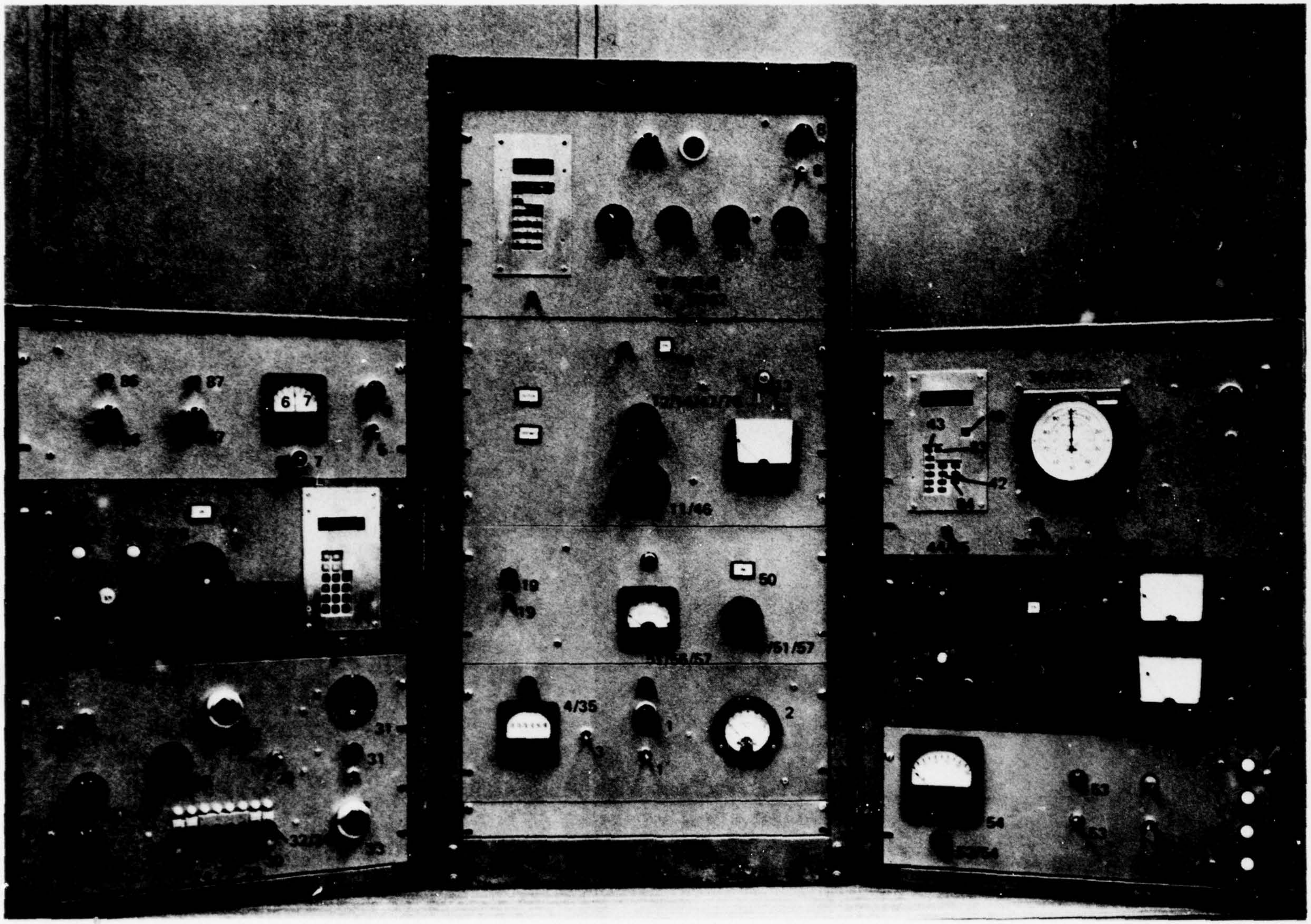


Figure 9 TASK SEQUENCE FOR INITIAL TRAINING TASK

1 Turn on main power

2 Check AC voltage*

3 Start failure clock

4 Note starting time

5 Turn on left sector power

6 Check negative polarity

7 Check positive polarity

8 Turn on center sector power

9 Turn on right sector power

10 Turn on power to conveyor

11 Set conveyor speed range*

12 Preset conveyor speed*

13 Delay until conveyor reaches speed

14 Fine adjust conveyor speed*

15 Set loader speed range*

16 Preset loader speed*

17 Turn on power to loader*

18 Set loader to initial speed*

19 Turn on heating element

20 Initiate first measurement

21 Set first measurement value (4)*

22 Initiate second measurement

23 Set second measurement value (5)*

24 Initiate fourth measurement

25 Set fourth measurement value (24)*

26 Initiate fifth measurement

27 Set fifth measurement value (207)*

28 Initiate sixth measurement

29 Set sixth measurement value (dn)*

30 Initiate seventh measurement

31 Set seventh measurement value (30)*

32 Initiate eighth measurement

33 Set eighth measurement value (775)*

34 Disengage seventh measurement

35 Check failure clock

36 Reset timer

37 Initiate calibrated component

38 Delay until component is loaded

39 Start timer

40 Note component reaches receiver

41 Stop timer

*indicates actions in which a setting error is also possible (in addition to sequence errors)

42 Input time into keyboard

43 Input time into memory

44 Record time on data tape

45 Calculate correct conveyor speed*

46 Set conveyor speed range appropriate*

47 Calibrate conveyor speed

48 Clear display

49 Preset temperature regulator*

50 Turn on regulator

51 Set temperature*

52 Preset air pressure*

53 Turn on air compressor

54 Set air pressure*

55 Turn on blower

56 Check temperature for change*

57 Recalibrate temperature

58 Initiate first coating condition

59 Set coating level (2)*

60 Initiate third coating condition

61 Set coating level (4)*

62 Initiate fourth coating condition

63 Set coating level (5)*

64 Preset receiver speed*

65 Turn on power to receiver

66 Set receiver speed range*

67 Set loader speed range to op. cond.*

68 Fine adjust loader speed*

69 Match loader speed & receiver speed

70 Reset timer

71 Initiate timing check component

72 Delay until component is loaded

73 Start timer

74 Monitor receipt of fast/slow comp.

75 Stop timer

76 Calibrate conveyor speed*

77 Reset timer

78 Initiate second timing ck. comp.

79 Delay until component is loaded

80 Start timer

*indicates actions in which a setting error is also possible (in addition to sequence errors)

81 Monitor receipt of component

82 Stop timer

83 Recall time from meas. trial

84 Input time difference*

85 Record difference on data tape

86 Put into "set-up" status

87 Put into "running" status

*indicates actions in which a setting error is also possible (in addition to sequence errors)

APPENDIX B

GENERAL DESCRIPTION AND
SEQUENCE OF STEPS IN TRANSFER TASK

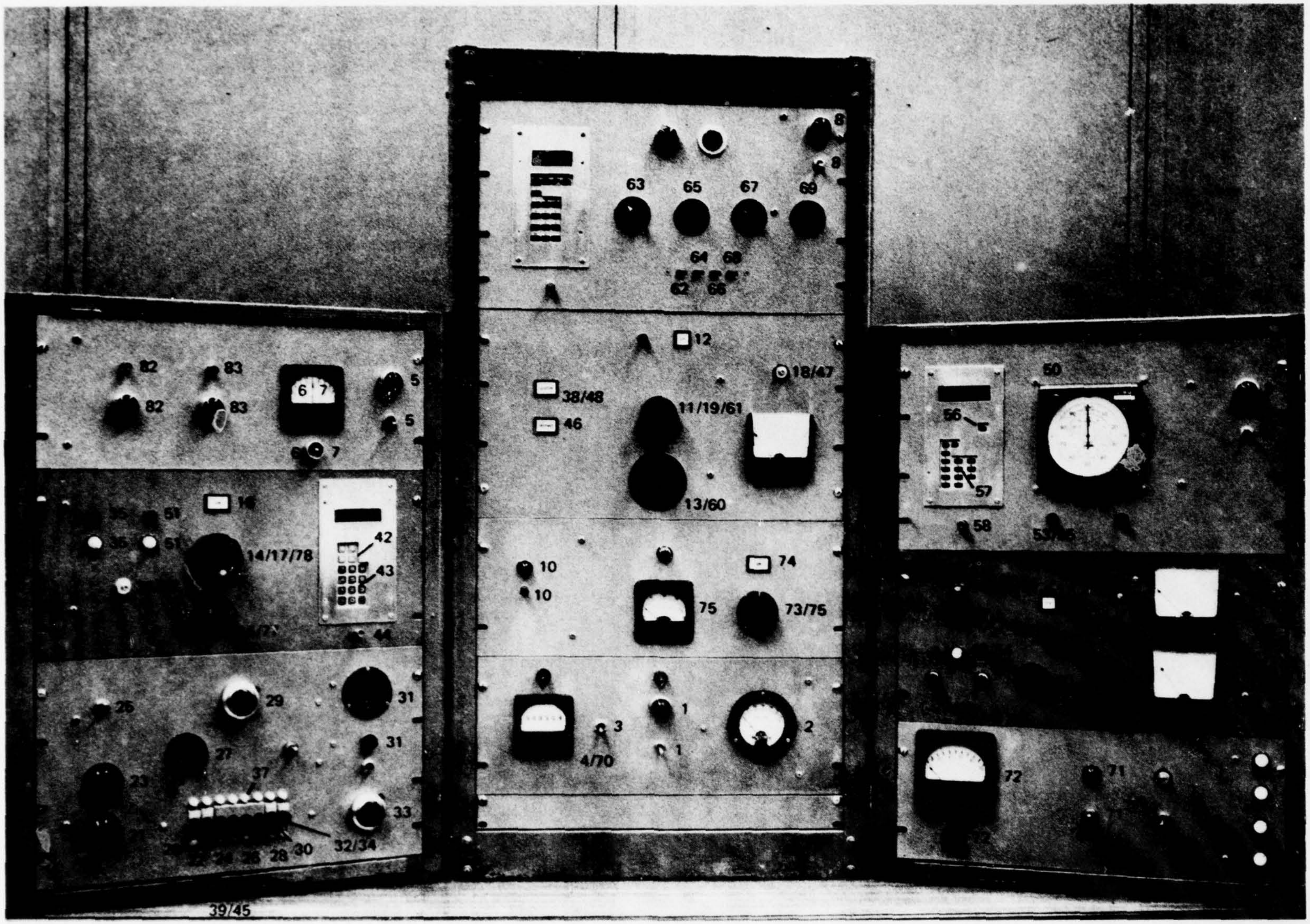


Figure 10 TASK SEQUENCE FOR TRANSFER TASK

Due to recent experience with the set-up procedure, a number of changes have been made to the procedure to make it more efficient.

The new general sequence of setting up the process is as follows:

(1)	1	Turn on the power to the equipment.
(2)	2	Turn on the conveyor.
(3)	3	Turn on the loader.
(3-1/2)	4	Fine adjustment of the conveyor.
(4)	5	Set up the measurements.
(5)	6	Check the measurements with a calibrated component.
-	7	If there is a problem, stop the conveyor and recalibrate measurements.
-	8	Restart the conveyor.
(11)	9	Use a *timing* component to recalibrate the conveyor.
(8)	10	Set up the paint coatings.
(7)	11	Set up the drying equipment.
(10)	12	Set the loader to operating speed.
(9,10)	13	Turn on and match the receiver to the loader speed.
(12)	14	Put the process into operation.

( ) indicates order in initial training task

(1)	1	Turn on main power
(2)	2	Check AC voltage (>115)
(3)	3	Start failure clock
(4)	4	Note starting time
(5)	5	Turn on left sector power
(6)	6	Check negative polarity
(7)	7	Check positive polarity
(8)	8	Turn on center sector power
(9)	9	Turn on right sector power
(19)	10	Turn on heating element
(12)	11	Preset conveyor speed (6 turns) *
(10)	12	Turn on power to conveyor
(11)	13	Set conveyor speed range (6-7) *
(16)	14	Preset loader speed
(15)	15	Set loader speed range (10-20) *
(17)	16	Turn on power to loader
(18)	17	Set loader to initial speed (15) *
(13)	18	Delay until conveyor reaches speed
(14)	19	Fine adjust conveyor speed (62) *
(20)	20	Initiate first measurement
(21)	21	Set first measurement value (2) *
(22)	22	Initiate second measurement
(23)	23	Set second measurement value (9) *
(24)	24	Initiate third measurement
(25)	25	Set third measurement value (UP) *
(-)	26	Initiate fourth measurement
(-)	27	Set fourth measurement value (15)
(26)	28	Initiate fifth measurement
(27)	29	Set fifth measurement value (840) *
(30)	30	Initiate seventh measurement
(31)	31	Set seventh measurement value (20) *
(32)	32	Initiate eighth measurement
(33)	33	Set eighth measurement value (235) *
(34)	34	Disengage seventh measurement
(-)	35	Initiate meas. calib component
(-)	36	Note component is loaded
(-)	37	Check for measurement error
(-)	38	Stop conveyor due to error
(-)	39	Select meas. initialization

( ) indicates sequence in original training task.
* indicates setting changes from original task.

(-)	40	Retract measurement tool
(-)	41	Recalibrate measurement tool
(-)	42	Clear display
(-)	43	Input calib. #
(-)	44	Put on data tape
(-)	45	Disengage measurement
(-)	46	Restart conveyor motor
(-)	47	Delay until motor reaches speed
(-)	48	Disengage clutch
(40)	49	Note component reaches receiver
(36)	50	Reset timer
(37)	51	Initiate timing component
(38)	52	Delay until component is loaded
(39)	53	Start timer
(40)	54	Note component reaches receiver
(41)	55	Stop timer
(48)	56	Clear display
(42)	57	Input time into keyboard
(44)	58	Record time on data tape
(45)	59	Calculate correct conveyor speed (X5) *
(46)	60	Set conveyor speed range* appropriate
(47)	61	Calibrate conveyor speed
(58)	62	Initiate first coating condition
(59)	63	Set coating level (4)*
(-)	64	Initiate second coating condition
(-)	65	Set coating level (1)*
(60)	66	Initiate third coating condition
(61)	67	Set coating level (2)*
(62)	68	Initiate fourth coating condition
(63)	69	Set coating level (6)*
(35)	70	Check failure clock
(53)	71	Turn on air compressor (UP)*
(54)	72	Set air pressure (45)*
(49)	73	Preset temperature regulator
(50)	74	Turn on regulator
(51)	75	Set temperature (180°)*
(55)	76	Turn on blower
(67)	77	Set loader speed range to op. cond.

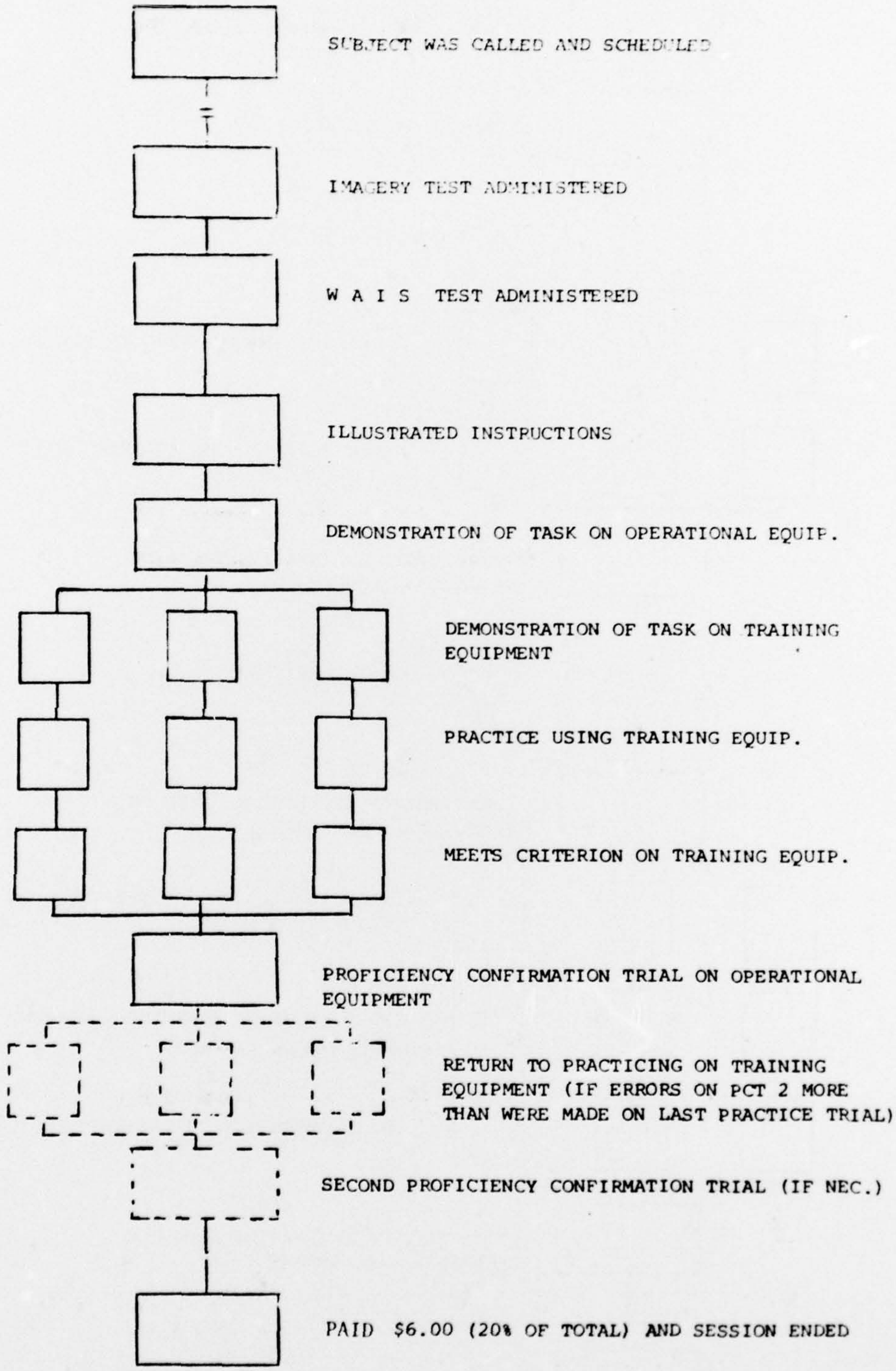
( ) indicates sequence in original training task.
* indicates setting changes from original task.

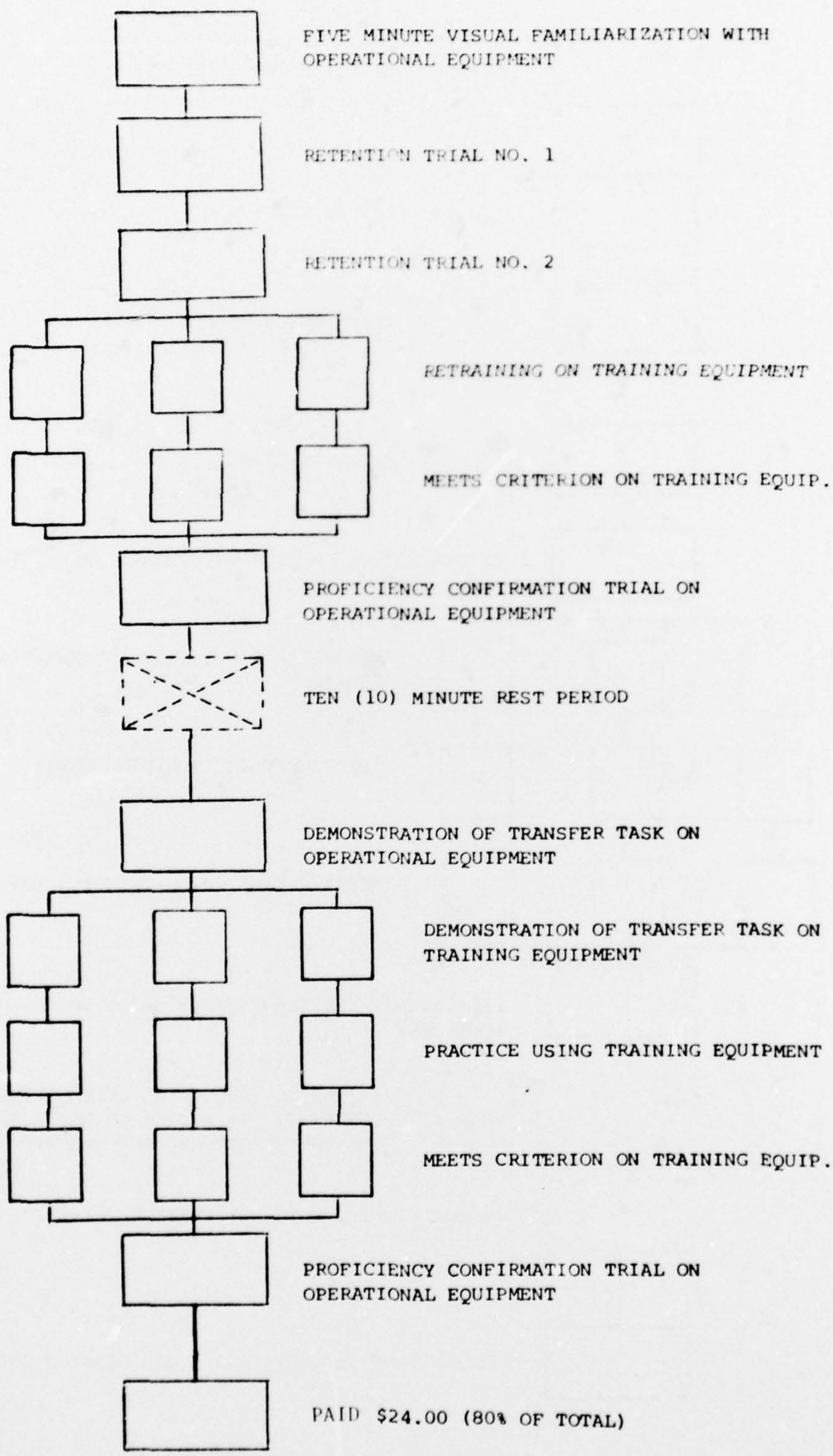
(68)	78	Fine adjust loader speed (30)*
(65)	79	Turn on power to receiver
(66)	80	Set receiver speed range (3-4)
(69)	81	Match loader speed & receiver speed
(86)	82	Put into "set-up" status
(87)	83	Put into "running" status

( ) indicates sequence in original training task.
* indicates setting changes from original task.

APPENDIX C

DIAGRAM OF EXPERIMENTAL PROCEDURE


SUBJECT WAS CALLED AND SCHEDULED
IMAGERY TEST ADMINISTERED
W A I S TEST ADMINISTERED
ILLUSTRATED INSTRUCTIONS
DEMONSTRATION OF TASK ON OPERATIONAL EQUIP.
DEMONSTRATION OF TASK ON TRAINING EQUIPMENT
PRACTICE USING TRAINING EQUIP.
MEETS CRITERION ON TRAINING EQUIP.
PROFICIENCY CONFIRMATION TRIAL ON OPERATIONAL EQUIPMENT
RETURN TO PRACTICING ON TRAINING EQUIPMENT (IF ERRORS ON PCT 2 MORE THAN WERE MADE ON LAST PRACTICE TRIAL)
SECOND PROFICIENCY CONFIRMATION TRIAL (IF NEC.)
PAID $6.00 (20% OF TOTAL) AND SESSION ENDED


FIVE MINUTE VISUAL FAMILIARIZATION WITH OPERATIONAL EQUIPMENT
RETENTION TRIAL NO. 1
RETENTION TRIAL NO. 2
RETRAINING ON TRAINING EQUIPMENT
MEETS CRITERION ON TRAINING EQUIP.
PROFICIENCY CONFIRMATION TRIAL ON OPERATIONAL EQUIPMENT
TEN (10) MINUTE REST PERIOD
DEMONSTRATION OF TRANSFER TASK ON OPERATIONAL EQUIPMENT
DEMONSTRATION OF TRANSFER TASK ON TRAINING EQUIPMENT
PRACTICE USING TRAINING EQUIPMENT
MEETS CRITERION ON TRAINING EQUIP.
PROFICIENCY CONFIRMATION TRIAL ON OPERATIONAL EQUIPMENT
PAID $24.00 (80% OF TOTAL)

APPENDIX D

SHEEHAN'S SHORT FORM OF THE
BETTS QUESTIONNAIRE UPON MENTAL IMAGERY

(Adapted from Richardson, 1969)

SUBJECT NO.: ______________

Instructions for doing test

The aim of this test is to determine the vividness of your imagery. The items of the test will bring certain images to your mind. You are to rate the vividness of each image by reference to the accompanying rating scale, which is shown at the bottom of the page. For example, if your image is 'vague and dim' you give it a rating of 5. Record your answer *in the brackets* provided after each item. Just write the appropriate number after each item. Before you turn to the items on the next page, familiarize yourself with the different categories on the rating scale. Throughout the test, refer to the rating scale when judging the vividness of each image. A copy of the rating scale will be printed on each page. Please do not turn to the next page until you have completed the items on the page you are doing, and do not turn back to check on other items you have done. Complete each page before moving on to the next page. Try to do each item separately independent of how you may have done other items.

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience — *Rating* 1

Very clear and comparable in vividness to the actual experience — *Rating* 2

Moderately clear and vivid — *Rating* 3

Not clear or vivid, but recognizable — *Rating* 4

Vague and dim — *Rating* 5

So vague and dim as to be hardly discernible — *Rating* 6

No image present at all, you only 'knowing' that you are thinking of the object — *Rating* 7

An example of an item on the test would be one which asked you to consider an image which comes to your mind's eye of a red apple. If your visual image was moderately clear and vivid you would check the rating scale and mark '3' in the brackets as follows:

Item	*Rating*
5. A red apple	(3)

Now turn to the next page when you have understood these *instructions and begin the test.*

Think of some relative or friend whom you frequently see, considering carefully the picture that rises before your mind's eye. Classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item	*Rating*
1. The exact contour of face, head, shoulders and body	( )
2. Characteristic poses of head, attitudes of body, etc.	( )
3. The precise carriage, length of step, etc. in walking	( )
4. The different colours worn in some familiar costume	( )

Think of seeing the following, considering carefully the picture which comes before your mind's eye; and classify the image suggested by the following question as indicated by the degree of clearness and vividness specified on the Rating Scale.

5. The sun as it is sinking below the horizon	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience — *Rating* 1

Very clear and comparable in vividness to the actual experience — *Rating* 2

Moderately clear and vivid

* This scale was constructed as part of N.I.M.H. Project M-3950; J. P. Sutcliffe, Principal Investigator.

Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

Think of each of the following sounds, considering carefully the image which comes to your mind's ear, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item	*Rating*
6. The whistle of a locomotive	( )
7. The honk of an automobile	( )
8. The mewing of a cat	( )
9. The sound of escaping steam	( )
10. The clapping of hands in applause	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience	*Rating* 1
Very clear and comparable in vividness to the actual experience	*Rating* 2
Moderately clear and vivid	*Rating* 3
Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

Think of 'feeling' or touching each of the following, considering carefully the image which comes to your mind's touch, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item	*Rating*
11. Sand	( )
12. Linen	( )
13. Fur	( )
14. The prick of a pin	( )
15. The warmth of a tepid bath	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience	*Rating* 1
Very clear and comparable in vividness to the actual experience	*Rating* 2
Moderately clear and vivid	*Rating* 3
Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

Think of performing each of the following acts, considering carefully the image which comes to your mind's arms, legs, lips, etc., and classify the images suggested as indicated by the degree of clearness and vividness specified on the Rating Scale.

Item	*Rating*
16. Running upstairs	( )
17. Springing across a gutter	( )
18. Drawing a circle on paper	( )
19. Reaching up to a high shelf	( )
20. Kicking something out of your way	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience	*Rating* 1
Very clear and comparable in vividness to the actual experience	*Rating* 2
Moderately clear and vivid	*Rating* 3
Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

Think of tasting each of the following considering carefully the image which comes to your mind's mouth, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item	*Rating*
21. Salt	( )
22. Granulated (white) sugar	( )
23. Oranges	( )
24. Jelly	( )
25. Your favourite soup	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience	*Rating* 1
Very clear and comparable in vividness to the actual experience	*Rating* 2
Moderately clear and vivid	*Rating* 3
Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

Think of smelling each of the following, considering carefully the image which comes to your mind's nose and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item	*Rating*
26. An ill-ventilated room	( )
27. Cooking cabbage	( )
28. Roast beef	( )
29. Fresh paint	( )
30. New leather	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience	*Rating* 1
Very clear and comparable in vividness to the actual experience	*Rating* 2
Moderately clear and vivid	*Rating* 3
Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

Think of each of the following sensations, considering carefully the image which comes before your mind, and classify the images suggested as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item	*Rating*
31. Fatigue	( )
32. Hunger	( )
33. A sore throat	( )
34. Drowsiness	( )
35. Repletion as from a very full meal	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience	*Rating* 1
Very clear and comparable in vividness to the actual experience	*Rating* 2
Moderately clear and vivid	*Rating* 3
Not clear or vivid, but recognizable	*Rating* 4
Vague and dim	*Rating* 5
So vague and dim as to be hardly discernible	*Rating* 6
No image present at all, you only 'knowing' that you are thinking of the object	*Rating* 7

APPENDIX E

GORDON TEST OF VISUAL IMAGERY CONTROL
(Adapted from Richardson, 1969)

You have just completed a questionnaire that was designed to measure the *vividness* of different kinds of imagery. In this present questionnaire some additional aspects of your imagery are being studie.

The questions are concerned with the ease with which you can *control* or *manipulate* visual images. For some people this task is relatively easy and for others relatively hard. One subject who could not manipulate his imagery easily gave this illustration. He visualized a table, one of whose legs suddenly began to collapse. He then tried to visualize another table with four solid legs, but found it impossible. The image of the first table with its collapsing leg persisted. Another subject reported that when he visualized a table the image was rather vague and dim. He could visualize it briefly but it was difficult to retain by any voluntary effort. In both these illustrations the subjects had difficulty in controlling or manipulating their visual imagery. It is perhaps important to emphasize that these experiences are in no way abnormal and are as often reported as the controllable type of image.

Read each question, then close your eyes while you try to visualize the scene described. Record your answer by underlining 'Yes', 'No' or 'Unsure', whichever is the most appropriate. Remember that your accurate and honest answer to these questions is most important for the validity of this study. If you have any doubts at all regarding the answer to a question, underline 'Unsure'. Please be certain that you answer each of the twelve questions.

1. Can you see a car standing in the road in front of a house?	Yes	No	Unsure
2. Can you see it in colour?	Yes	No	Unsure
3. Can you now see it in a different colour?	Yes	No	Unsure
4. Can you now see the same car lying upside down?	Yes	No	Unsure
5. Can you now see the same car back on its four wheels again?	Yes	No	Unsure
6. Can you see the car running along the road?	Yes	No	Unsure
7. Can you see it climb up a very steep hill?	Yes	No	Unsure
8. Can you see it climb over the top?	Yes	No	Unsure
9. Can you see it get out of control and crash through a house?	Yes	No	Unsure
10. Can you now see the same car running along the road with a handsome couple inside?	Yes	No	Unsure
11. Can you see the car cross a bridge and fall over the side into the stream below?	Yes	No	Unsure
12. Can you see the car all old and dismantled in a car-cemetery?	Yes	No	Unsure

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

training	cognitive style
retention	training strategy
imagery	transfer of training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study investigated the effectiveness of three different training strategies with respect to initial training, retention, and transfer of training. In addition to investigating the relative merits of the three strategies, the possibility of matching the instructional strategy and the trainee's cognitive style was evaluated. There is growing research support for the contention that different individuals utilize different means of encoding and/or storing information. The effect of these differences with

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respect to initial training, retention, and transfer of training was addressed in the context of a realistic task. The particular task used was representative of the many sequential procedures performed which range from operating master control panels in industrial plants to normal and emergency procedures in air vehicles.

The instructional strategies evaluated during the study were designed to require varying degrees of imagery utilization through reductions in the stimuli that provide visual cueing and feedback. The standard for comparing the effectiveness of these strategies was the conventional "repetition" of the task on the operational equipment or high fidelity mockups (simulations) of the equipment. The individual trainee's vividness of mental imagery was the aspect of cognitive style that was investigated with respect to performance within the three training strategies.

The results of the study indicate that: (1) vividness of imagery does interact with training strategy, (2) training devices do not need high fidelity to be effective in training procedural tasks, and (3) the use of training strategy that requires the trainee to provide his own cueing and feedback from memory is effective in increasing the retention of procedure-following skills, independent of cognitive style. These results have important implications for both the dollar cost and logistics of initial and refresher training, as well as for the retention efficiency of an important aspect of the human's present job description.